UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 933

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. PROFESSIONAL PAPER March 8, 1921

BLACK WALNUT
ITS GROWTH AND MANAGEMENT

By

F. S. BAKER, Forest Examiner

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By F. S. BAKER, *Forest Examiner.*

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INTRODUCTION.

The importance of black walnut (*Juglans nigra*, Linn.) was impressed upon the whole Nation by the efforts made during the war to secure black-walnut wood for gunstocks and airplane propellers. The supply, which has never been large in comparison with the supply of other woods, was greatly depleted to satisfy these war-time demands. The demand for black walnut has continued strong since the close of the war period, and comparatively high prices have been maintained. Even during peace times there is sure to be a constant though moderate call for walnut and at higher prices than are obtained for most other North American woods.

In order that the supply of black walnut may not be inadequate for manufacturing needs in the event of another war, there should be a reserve of growing timber. Whatever the Government may accomplish in this direction on its own lands, every farm within the range of walnut growth on which trees of this species are found is potentially a part of such a reserve. Obviously, black walnut is a very valuable element of any timberland or farm wood lot in which it grows. Great importance, therefore, attaches to the questions of available supply, growth, and management of black walnut, and of the financial possibilities of growing it for the timber market. It is the purpose of this bulletin to present such information as is available on these subjects.

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DISTRIBUTION OF WALNUT.

BOTANICAL RANGE.

That there is a considerable quantity of walnut still left in the country is due to the immense area on which the species grows and not to the presence of large supplies in any one region. The botanical

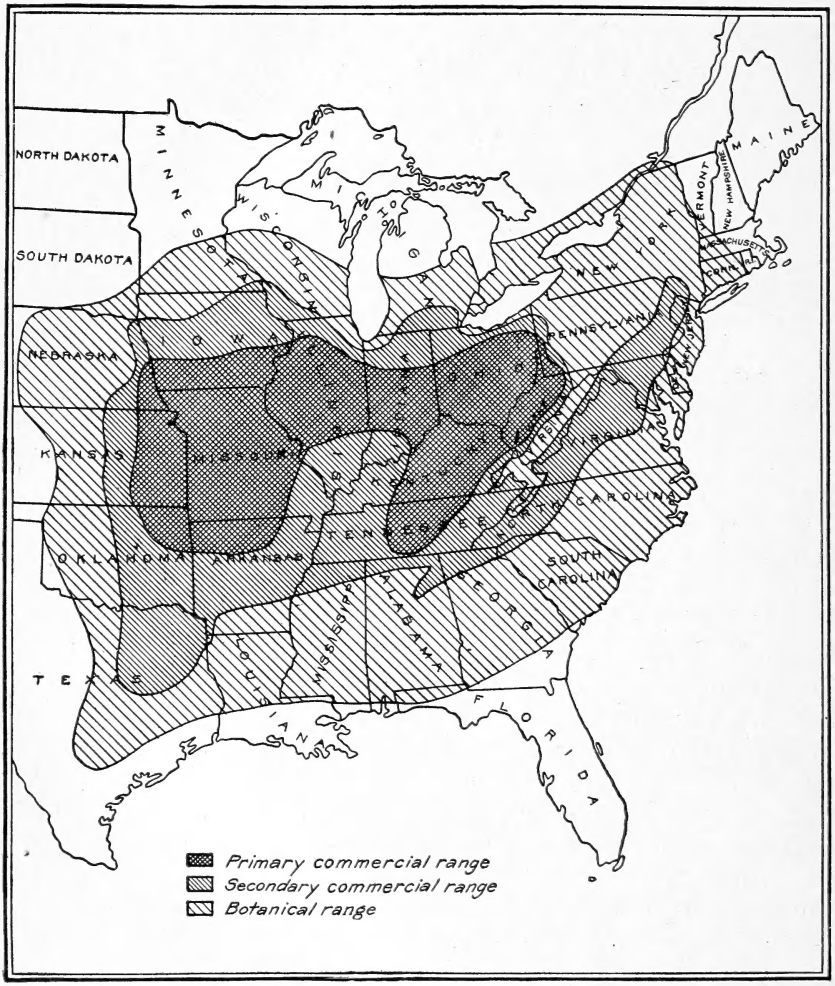

FIG. 1.—The range of black walnut.

range, as shown in figure 1, is from southern New England and Ontario to Minnesota, South Dakota, and Nebraska, south into Texas and east to Georgia, reaching the Atlantic coast line in South Carolina. Planting has introduced walnut into every State in the Union,

although usually in the sections outside its range occasional shade trees only are found.

COMMERCIAL RANGE.

The commercial range is also very wide, extending in places almost to the limits of the botanical range, the value of walnut being sufficient to warrant the cutting and shipment of amounts as small as part of the range from as far as Kerrville, Uvalde, and New Braunpoint.

During the war the commercial range was probably wider than ever before except toward the southwest, where the quality of the wood is unsuitable for lumber. Some of the outlying shipping points in the northern part of the range were Crofton, Nebr. (some of the logs coming from near Yankton, S. Dak.), Garden City, Minn., and Ferryville and Madison, Wis. Michigan shipments have come from as far as 80 miles north of the Indiana line and from an island in the Detroit River. In the northeastern part of the range, the region about Geneseo, N. Y., and Long Island mark the outermost points at which commercial amounts have been found. In the southeastern portion logs have come from the region of Columbia, S. C., from a mill operated for a time at Columbus, Ga., and from another at Montgomery, Ala., although only a part of the logs were obtained in the locality. West of the Mississippi, logs have come from as far south as Shreveport, La., and along the Red River; and in the southwestern part of the range from as far as Kerrville, Uvalde, and New Braunfels, Tex. In the western region logs came from as far as Thomas, Okla.; Great Bend, on the Arkansas River in Kansas; and Stockton, on the Solomon. No records of shipments have come from very far west in Nebraska, Crete being about the limit.

The best natural development of walnut is to be found probably in the Ohio River Basin, in the southern Appalachians, or in Arkansas. The best groves placed on the market in late years were at Danville, Ill., and Excelsior Springs, Mo.; but this was because the old original stands had been preserved through the personal desires of the owners rather than because of any exceptional growing conditions. That exceptionally large trees are not limited to any particular region is shown by the widely distant points from which large logs have been obtained for various expositions. A 12-foot log, 52 inches in diameter, from Jackson County, N. C., was exhibited at the Centennial Exposition, Philadelphia, in 1876; and a 16-foot log, 77 inches in diameter, from Mormon Creek, Bates County, Mo., at the World's Fair, Chicago, in 1893. A 20-foot log, 52 inches in diameter, from the Osage Reservation of the Indian Territory, was secured for exhibition at the Paris Exposition, in 1900.

INFLUENCE OF SOIL AND CLIMATE UPON DISTRIBUTION.

Throughout its wide range the local distribution of walnut is controlled by climatic and soil factors, which affect not only its abundance and commercial value but also the other species with which it characteristically associates in the forest. In general, walnut is found on rich, moist but well-drained soils. It is more dependent upon these conditions than are many of its associates, and a relatively slight inferiority in any of these respects may be reflected either in a scarcity of walnut or in slow and scrubby growth. Its dependence upon good soil is more marked, however, in regions in the western part of its range, which have a relatively scant precipitation, than it is in well-watered regions like those in the southern Appalachians. In the latter situations it makes a better development on rocky and shallow, though by no means sterile, soils than could be expected elsewhere, compensation for the deficiency in soil qualities being made by the abundance of the summer rains.

West of the Wabash River and in the Mississippi Valley below Illinois walnut of good development is almost invariably on rich bottom lands. An exception to this is its occurrence in the Boston Mountains of Arkansas, where because of the heavier precipitation it is found on flat mountain tops and benches. It is, however, by no means a stream-bank tree in the sense in which sycamore, river birch, and willow are. These species, though frequently growing near by, are rarely seen in intimate mixture with walnut except in the moister places in the eastern part of its range. This is probably because the soil for walnut must be not only moist but well drained and aerated as well—a fact which, no doubt, also explains in large measure the lack of walnut in such places as the Mississippi bottom lands, which are subject to protracted flooding. The deficiency in soil aeration may also be responsible for the exceedingly slow growth and virtual failure of certain plantations on rich but exceedingly compact bottom-land soils, heavily sodded and never thoroughly broken.

LOCAL FORMS OF GROWTH AND ASSOCIATED SPECIES.

Walnut is found in three characteristic situations—as scattered field and fence-corner trees, as scattered trees in hardwood stands, or as pure stands, usually on the edge of the hardwood forest.

In fields, particularly in the Ohio River basin, it sometimes represents a remnant of the original stand, left because of its value when the land was cleared for agriculture. The fence-corner trees have come up because the uncultivated soil attracted squirrels to bury the nuts there and because in such situations the trees were protected from injury. Ever since the days of the great popularity of walnut furniture there has been a tendency among farmers to conserve this

tree more than associated species, partly because of a vague notion that it had exceptional value and partly, no doubt, on account of the yield of nuts.

As scattered trees in the hardwood forest, black walnut is found throughout the eastern part of the country, and here it is not restricted to the bottom lands. It usually forms a very small proportion of the total stand, especially in the Southeastern States, where the forest is composed of a great variety of species. In the Ohio River basin it is found in most of the open wood lots, where constant culling is reducing the stand and grazing is preventing all reproduction. In the repeated cuttings that have gone on in these groves for the last 30 years, walnut trees too small to be merchantable were often left to grow, in the hope that the earlier demand for walnut would be renewed. West of the Mississippi walnut becomes a more prominent component of the river-bottom forests, and in parts of eastern Kansas and Nebraska it is distinctly the dominant, sometimes practically the only, member of the stand.

Pure stands of walnut are somewhat common in much of the Ohio River basin, where they are typically found adjoining stands of mixed hardwoods and extending as open groves into pasture lands. These groves are valuable sources of supply, for the trees are fairly uniform in size and are much less expensive to market than are scattered trees. Pure stands of walnut are also frequent in certain localities in the western part of its range, although the stands as a rule contain an admixture of elm and hackberry at least, and frequently a number of other species. Pure stands are rarely dense enough to keep out grass, but the sod is usually not normally thick in these places.

The wide range of walnut involves its association with a vast number of other species, from basswood and hemlock in the northern part of its range to holly and shortleaf pine in the southern part. In the Ohio-Indiana region it is found most frequently with ash, oaks, beech, maple, hickory, elm, cherry, and Kentucky coffeetree. South of the Ohio River the most prominent difference is the association of red cedar and walnut, which is especially characteristic in Kentucky and middle Tennessee. In the Appalachian Mountain walnut is widely scattered, but reaches its best development on bottom lands and coves below 4,000 feet in elevation. Its associates are very numerous in this region, red oak, white oak, yellow poplar, and chestnut being the chief. In Illinois its more common associates in the river-bottom hardwood types are oaks, white elm, and ash. Toward northern Illinois and Wisconsin basswood and sugar maple become more important, but do not extend far over into Iowa. West of the Mississippi white elm, oaks, hackberry, and to a lesser extent hickory

(*Hicoria minima*) are typically found with walnut. Cottonwood is exceedingly common along streams, but it is more frequently an inhabitant of the bars and sandy banks of the large rivers than of the deep, rich soils of the smaller stream bottoms where the walnut is found. In Kansas, elm, hackberry, and walnut are constantly found together in stands of varying composition as far south as the Arkansas River, where a flora more characteristically southern, containing various oaks, makes up much of the valley forest. Wherever Kentucky coffeetree, is found walnut is almost invariably present, and this tree may be accepted as a trustworthy indicator of a site suitable for black walnut.

SUPPLY.

The supply of black walnut has been reduced in much the same way as that of all our hardwoods since the settlement of this country. Certain factors, however, notably the value of both the tree itself and the soil it thrives on, have together induced a comparatively rapid decrease in the amount of black walnut, which never was really abundant. Therefore we now have less of this than of any other commercially important wood, with the exception of cherry and, possibly, black locust.

ESTIMATED STAND BY STATES.

To make a definite statement in regard to walnut resources at this time would be quite impossible, because the trees are so widely scattered and so seldom found in any large quantity that authentic figures for even limited regions are difficult to obtain. The fact that such large amounts came to light during the war has led to overoptimistic estimates in many quarters, as a sort of reaction from the unduly low estimates that were popular for many years before the war. The best information at hand gives the present stand for the country as 821 million feet, distributed among 28 States, as shown in Table 1. Of this amount probably 50 per cent is inaccessible to the manufacturers, half of this on account of the unwillingness of owners to sell at any price and half on account of the excessive cost of getting the timber out from the remote valleys of the southern Appalachians and Ozarks. Even at war prices hauls of over 20 miles to railroads were very rare, and all timber farther removed is virtually inaccessible. The remaining 50 per cent consists of material generally smaller and of poorer quality than existed in the older stands, and in the East it is very largely in the form of scattered field and fence-corner trees and of shade trees about the farm.

TABLE 1.—*Estimated amount of standing walnut, in millions of board feet, by States. (Trees 12 inches in diameter and over, breast high.)*[1]

Middle Atlantic States	30
New York	2
New Jersey	2
Pennsylvania	26
South Atlantic States	64
Delaware	1
Maryland	5
Virginia	29
North Carolina	14
South Carolina	7
Georgia	8
North Central States	211
Ohio	63
Southern Michigan	15
Indiana	44
Southern Wisconsin	10
Illinois	79
South Central States	187
West Virginia	60
Kentucky	67
Tennessee	60
Prairie States	215
Minnesota	3
Iowa	60
Missouri	107
Nebraska	18
Kansas	27
Southern States	114
Arkansas	46
Oklahoma	18
Texas	37
Louisiana	3
Mississippi	4
Alabama	6
Total	821

IMPORTANCE OF WALNUT IN THE DIFFERENT STATES.

NEW ENGLAND STATES.

The stand of walnut in the New England States, except in western Connecticut, is confined to scattered planted trees.

[1] It is not claimed that these quantities are accurate. They are very general approximations based upon the best available evidence, and should be held subject to correction on the basis of future timber estimates.

MIDDLE ATLANTIC STATES.

New York.—Although the entire State of New York lies within the botanical range of black walnut, there are only a few places where the species exists plentifully. Sullivan and Orange Counties, in the southeastern part of the State, contain commercial amounts; but on the west bank of the Hudson, above Newburgh, and from the Hudson eastward as far as, but not including, Long Island, it is very scattered. In the Genessee Valley, especially in Livingston County, walnut is found in amounts sufficiently large to warrant commercial exploitation if the demands were similar to those of war time.

New Jersey.—Walnut is plentiful in the western part of New Jersey, especially in Sussex, Warren, Hunterdon, and Cumberland Counties, being, of course, most abundant and of the best quality on the better soils. On the sandy soils farther east its growth is slower and its quality inferior, although large trees are frequently found.

Pennsylvania.—In the northern and central parts of Pennsylvania walnut is very rare. West and southwest of this region of scarcity lies a belt in which walnut is somewhat common on the good soils of the valleys, but is lacking in the mountains. The southwestern and southeastern parts of the State contain stands of walnut scattered very generally throughout the hardwood forests, particularly in the larger valleys.

SOUTH ATLANTIC STATES.

Maryland.—Valuable stands are found only in the western part of Maryland. The infertile red clays prevailing farther east and the sands of the coast belt are not favorable to a good development of walnut.

Delaware.—Only the northernmost portion of Delaware contains native walnut of high quality.

Virginia.—The Shenandoah Valley remains the best walnut region of Virginia, although the abundance of walnut there has been greatly reduced. Commercial quantities are still to be found throughout the whole length of the valley, as well as in the coves and valleys on both sides of the mountains. On the east slope of the Blue Ridge a considerable amount of walnut is found in small, fertile mountain valleys. To a lesser extent it grows on the slopes of these small valleys but is of inferior quality. In the Piedmont region the river valleys contain considerable walnut, the Potomac and Rappahannock basins contain the most, and the York and James somewhat less. South of this region walnut is scarce, and is found in carload lots only in the broadest of the bottom lands, the poor red soils of the uplands being unfavorable to its development. On the coastal plain of Virginia walnut is rare.

FIG. 1.—NATURAL GROVE OF BLACK WALNUT IN DECATUR COUNTY, IND.

FIG. 2.—OPEN WOODLOT IN INDIANA, IN WHICH BLACK WALNUT IS CHARACTERISTICALLY GROWING IN MIXTURE WITH OAKS AND OTHER HARDWOODS. SOME WALNUT TREES HAVE RECENTLY BEEN CUT.

FIG. 1.—GROVE OF BLACK WALNUT IN INDIANA, FRINGING MIXED HARDWOOD STAND AT RIGHT.

FIG. 2.—WHITE OAK COMING IN UNDER BLACK WALNUT THAT FIRST INVADED THE PRAIRIE SOD.

IN THE APPALACHIAN MOUNTAINS BLACK WALNUT OCCURS IN MIXTURE WITH CHESTNUT, YELLOW POPLAR, RED OAKS, AND HICKORIES. VIEW IN SWAIN COUNTY, N. C.

North Carolina.—The coves and valleys of the mountain region of western North Carolina up to an elevation of 4,000 feet are the most favorable sites in the State for walnut. For many years these forests have been subjected to selective logging, carried on at greater and greater distances from shipping points, and the walnut has been removed along with other valuable species. This process culminated in the close search for walnut during the war. As a result, stands containing much walnut of merchantable size and quality can now rarely be found in the western part of the State, except in remote sections distant from railroads or in places otherwise difficult of access. In the Piedmont region it is found commonly as far east as a line relatively parallel to the mountains and passing through Statesville, and in this region perhaps the largest amounts in the State exist at the present time. Still farther east walnut is occasionally found on better bottom lands, but in many large areas it is entirely lacking, although hedgerow and roadside trees which have been protected are not infrequent.

South Carolina.—As a whole, walnut is not commercially important in South Carolina, being found in quantity only in the one tier of counties next to the mountains. Throughout the Piedmont region, as far as Columbia, it is usually found only as scattered trees on rich soils, but in some localities it is more abundant.

Georgia.—Walnut is of importance only in the Appalachian Valley region of northeast Georgia and the Blue Ridge region to the east, where a few counties contain 40 per cent of the total stand. Toward the southeast the proportion of native walnut decreases, and along the two or three rows of counties back from the coast nothing but planted walnut or protected roadside trees is reported. Nowhere is there now sufficient walnut to give the section any commercial importance, and the scattered walnut of the Piedmont region is hardly more considerable.

NORTH CENTRAL STATES.

Ohio.—Ohio is one of the famous old producers, and, in spite of a somewhat dense population and large agricultural area, there are still large amounts of walnut to be found, especially in the broken east central part of the State, where it flourishes in fields and in mixed hardwood stands and seems to be reproducing in a satisfactory way. It is common but less plentiful over the remainder of the State.

Southern Michigan.—Although a famous hardwood State, Michigan is too far north to have very much walnut. This wood has been shipped from as far north as the fourth tier of counties above the Indiana line, a distance of 80 miles. Toward the southwest, on account of the sandy soils, it is only occasionally found, but over

most of the two southern tiers of counties it is plentiful as a field tree. The quality is excellent to its northern commercial limit.

Indiana.—The whole State of Indiana has a high reputation for black walnut, but at present the species is irregularly distributed, a condition that is explained by the differences in the soil and by the settling and clearing of the land for agriculture. The northwest part of the State never has been to any great extent a walnut section, the poorly drained lands of the Kankakee River and the sandy stretches about the south end of Lake Michigan being unfavorable to this species. In the northeastern part of the State and in a region south of the Wabash River, embracing all but the lower third of the State, soils are excellent, and walnut is everywhere seen in fields, along roads, in wood lots, and especially west of Indianapolis, in pure groves fringing mixed hardwood stands. The south third of the State is more rolling and broken, and walnut is largely confined to valleys and protected slopes. The soils in some places are sterile clays underlaid by hardpan or rock, and are unfavorable for walnut, which is, therefore, scarce in these localities. In the region as a whole, however, walnut is of commercial importance. The forests of the Wabash Valley below Vincennes and of the Ohio Valley below Evansville tend toward types more characteristically southern, and walnut becomes more rare.

Southern Wisconsin.—Walnut exists in commercial quantities in southwest Wisconsin below a line running from La Crosse to Baraboo and Madison. It is nowhere very evident, but rich pockets of pure stands are found in out-of-the-way valleys. The trees usually grow as pure grooves in grassy hollows or scattered singly among the other species in the better class of hardwood stands. Walnut grows much farther north in Wisconsin, but is sparsely distributed, usually as widely scattered individual trees.

Illinois.—Most of the walnut in Illinois is found north of a line from St. Louis to Terre Haute, and is generally limited to the bottom lands and moist flats. Walnut is an important element of the hardwood stands in this region and is particularly abundant in the central part of the State. On the poorly drained and sandy soils in northeastern Illinois there is less walnut, and in the hardwood forests of southern Illinois it forms a smaller proportion of the stand than in the bottom-land forests farther north.

SOUTH CENTRAL STATES.

West Virginia.—The walnut in West Virginia is largely confined to the northwestern half of the State. The elevation of the southeastern half of the State is in general too high and the soil is too shallow and poor for walnut, although there are many valleys which

contain a considerable amount of merchantable walnut, as well as much small growth. In the region of the Great Kanawha and New Rivers the walnut has been almost entirely removed. In the extreme southwestern part of the State there are scattered stands. Though walnut grows to good size in West Virginia, it is not so large, in general, as in Ohio or Indiana, and it is also more defective.

Kentucky.—Kentucky is a heavy producer of walnut and still contains large quantities in spite of long-continued cutting. The bluegrass region of central Kentucky is the main source of supply on account of the ease with which most of the timber may be obtained and because of its general distribution on nearly every farm and wood lot. The largest amounts, however, are in the mountains of eastern Kentucky, but these supplies have hitherto been inaccessible, even at high war prices, on account of the long hauls over inferior roads and the small amounts available in any one place. In extreme western Kentucky the principal forest is the more characteristically southern type of bottom-land hardwoods in which walnut is an insignificant member.

Tennessee.—Tennessee is divided into three walnut-producing districts—east, middle, and west Tennessee—each containing different topographical and forest types. East Tennessee is mountainous and contains a great deal of walnut scattered as field trees in the agricultural lands of the valleys and appearing quite generally in wood lots and in the hardwood type, where it makes excellent development. On pine lands it is more rarely seen and is of inferior form. In the mountains it is found up to 4,000 feet in elevation, usually in coves with rich, deep soil, along with yellow poplar and white and red oaks. In the rolling country of middle Tennessee it is a common tree, although its development is inferior to that in east Tennessee. In the aggregate there is probably more walnut in this section than in either of the other divisions of the State. It is found in limestone soils, even where outcrops indicate a shallow soil, and it frequently associates with red cedar. In the hollows and valleys of the limestone region it reaches excellent proportions. West Tennessee tends to the alluvial-bottom type and contains only a scattering of walnut.

PRAIRIE STATES.

Southern Minnesota.—There is very little walnut in Minnesota, although some has been cut in the two southern tiers of counties, where conditions are similar to those of northern Iowa.

Iowa.—Iowa is one of the most important sources of walnut, particularly in the southern and southeastern parts. The loess soils of this State are deep and rich, and the broad river bottoms present large areas of well-watered soils in which walnut thrives. Planted on the uplands, walnut usually grows slowly, and its development

is unsatisfactory. Along the Mississippi and Missouri Rivers it is found in draws leading down to the streams, where branches have been cut through the bluffs. These draws contain a considerable quantity of walnut which may be regarded as here marking the most northerly limit of growth in commercial amounts.

Missouri.—Missouri ranks first in the amount of its standing walnut. The distribution of the walnut is somewhat uneven on account of the diverse topographic, soil, and climatic conditions. North of the Missouri River these conditions resemble those of Iowa, and the river bottoms and moist draws support relatively large stands of walnut in mixture with oaks, elm, hackberry, and, sometimes, along larger streams, cottonwood. The quality is good, although the trees do not, as a rule, reach a very large size. South of the Missouri River, in the western part of the State not included in the Ozark Hills, the conditions are more like those of eastern Kansas, and the proportion of walnut to other hardwoods is even greater. The third division of Missouri—the Ozark region—occupies most of the State south of the Osage River. Here walnut is found everywhere in the bottom-land forests, though rarely in pure groves. On the slopes and uplands it is absent. In the aggregate there is a large amount still standing in the Ozark region, and in more remote districts there is doubtless much excellent stuff, for even at the height of the war demand walnut was seldom cut farther than 20 miles from the railroads. There are probably 2,200 square miles of this more remote section from which only the best veneer logs have been removed. Under present market and labor conditions this region is virtually inaccessible. The fourth region is the heavily wooded southeast portion of the State from St. Louis southward, comprising the Mississippi bottom lands. Walnut is found here, scattered through the bottom-land hardwood forest, but in quantities too small for general commercial exploitation.

Nebraska.—In the southeast corner or the State there is a great deal of walnut along stream bottoms, but north of the Platte it is less abundant, and is found in commercial amounts chiefly near the Missouri River in draws where creeks break through the bluffs.

Kansas.—In eastern Kansas walnut is a very prominent constituent of the bottom-land forests for long distances, frequently composing 30 per cent of the stand. It is nearly always associated with elm and is usually second in importance to this tree, which extends to drier lands than the walnut. Hackberry is very frequent, and bur oak, white oak, and many other species may also be found in smaller amounts. Occasionally the stand will be pure walnut over areas of 5 to 20 acres, but mixed stands are the rule. Walnut is sometimes found on the northern slopes of the river bluffs among oaks and elms, usually where the slope is gentle and the soil is deep, especially near

springs or seeps. Small streams usually have the most favorable bottom lands; such rivers as the Kansas and Arkansas deposit too much sand along their bottoms.

SOUTHERN STATES.

Arkansas.—Walnut is widely distributed in Arkansas, usually in the deep rich soils of the stream bottoms; but its growth in large quantities is mostly confined to the northern part of the State. In the northwestern region, known as the Boston Mountains, the physiographic and climatic conditions are such that walnut ceases to be a river-bottom tree and appears upon the level terraces and mountain tops, which alternate with steep escarpments. Here the soil is rich and deep, of limestone and sandstone origin, and bears a blue-grass sod in most places. The rainfall is greater than in other regions west of the Mississippi River and conditions more closely resemble those of central Kentucky and Tennessee. In much of Arkansas the walnut is difficult of access, as the stands are far from railroads and hauling is expensive.

Oklahoma.—Walnut is of considerable importance as a bottom-land tree in Oklahoma. In the western part of the State it is scattering or only locally abundant; but in the eastern part, the old Indian Territory, it is still very common, although a great deal was recently cut, and the remaining timber is therefore mostly small. This region contained the last of the virgin walnut. The wood is considered inferior to walnut grown farther north and is little sought for milling.

Texas.—Conditions are widely variable in Texas, and the development of walnut is correspondingly irregular. The species is found over the whole eastern part of the State, though it is nowhere very abundant at the present time, the region having been worked heavily for export during the last 20 years. On the lower stretches of the rivers the prevailing forest is of the southern hardwood bottom-land type, consisting mainly of gums, oaks, and cypress and containing little walnut; but toward central Texas the southern species drop out one by one, and walnut becomes increasingly important until the western limits of its range are reached, where it associates with Mexican walnut (*Juglans rupestris*). In the black-soil region the wood is dark and uniform, producing veneers of a deep brown color with even a purple or dark-greenish shade. Toward the limestone region of the Edwards Plateau, where the conditions of growth are severe, the wood is light in color, streaked with darker shades, and sometimes so variable and so dark lined as to pass for genuine Circassian walnut. Valuable burls also come from this region. Texas walnut is defective in general and at present is not often cut for milling.

Louisiana, Mississippi, and Alabama.—In Louisiana walnut is not found in the pine type and is rare in the alluvial bottom-land type—the two types which comprise by much the greater part of the forest area; but commercial amounts are sometimes found in the Red River Valley, in the northwestern corner of the State. In Mississippi walnut is widely scattered through the extensive alluvial bottom hardwood type, but is so scarce that shipments of logs from any part of the State are rare. Alabama has never figured as a walnut-producing State, most of this species being found in the northeastern part, in the valleys of the Tennessee and Coosa Rivers.

FUTURE SUPPLIES.

The future supply of walnut can not well be inferred from any statement of the present stand of merchantable timber, because in such a statement immature trees are not considered. An estimate of the average annual yield is much more expressive of what may be expected in the future. Previous to the war the average annual cut probably ran between 40 and 50 million board feet a year, and those most familiar with the situation believed that this represented fairly well the cut that might be sustained continuously. This was borne out by the discovery during the war that the country actually had much more merchantable walnut than anybody supposed, although the increase was due in part to closer utilization and the release, as an act of patriotism, of supplies not usually on the commercial market. The war cut heavily into the growing stock, however, and the yield for some years will be reduced. Nevertheless, if the amount of young growth is in normal proportion to the older trees there is no reason why the old sustained yield of 40 to 50 million board feet should not be resumed.

An estimate of the amount of immature timber is even more difficult to make than an estimate of the merchantable stuff. Among those informed, the opinion is common that in most of its range there is an abundance of young walnut down to 6 or 8 inches in diameter. There is an astonishing lack of reproduction below this size, except in the upper Ohio and eastern region. The trees now rated as unmerchantable—and this is particularly true in the western part—are, as a rule, not thrifty young trees, but older growth that has been suppressed and stunted, though still capable of recovery and of development into saw timber. From this source there is a fair assurance of a moderate supply of black walnut for, perhaps, 30 years, comparable in amount to the walnut cut during the 20 years before the war. If a great war should occur during the next 30 years much difficulty would be experienced in securing desirable amounts of walnut. It is too late now to provide for any material increase in

the supply during that period, although the situation may be somewhat ameliorated by the careful management and conservation of remaining stands. At the end of this period the remaining supply will begin to decrease unless active steps are now taken to secure an adequate replacement by extensive planting or by forest management to secure natural regeneration. The upper Ohio Valley and Appalachian region is too limited to maintain a very large output. There is absolutely no need, however, of our sacrificing a national asset like black walnut, which may be perpetuated if the proper action is taken.

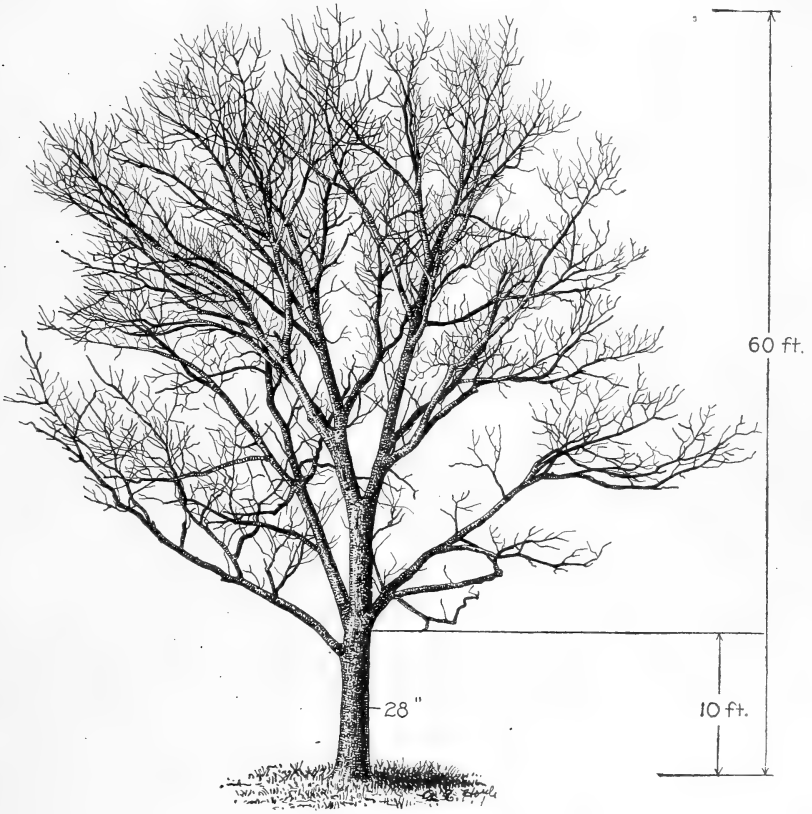

FIG. 2.—Open-grown black walnut tree.

DESCRIPTION OF THE TREE.

SIZE AND FORM.

Black walnut is naturally a large tree, and, if it were given time and a favorable site, it would grow to magnificent proportions. At present, however, it is a rare thing to see trees over 30 inches in diameter, breast high, and these are usually open grown with broad-spreading crowns and short trunks. Logs as large as 77 inches at the

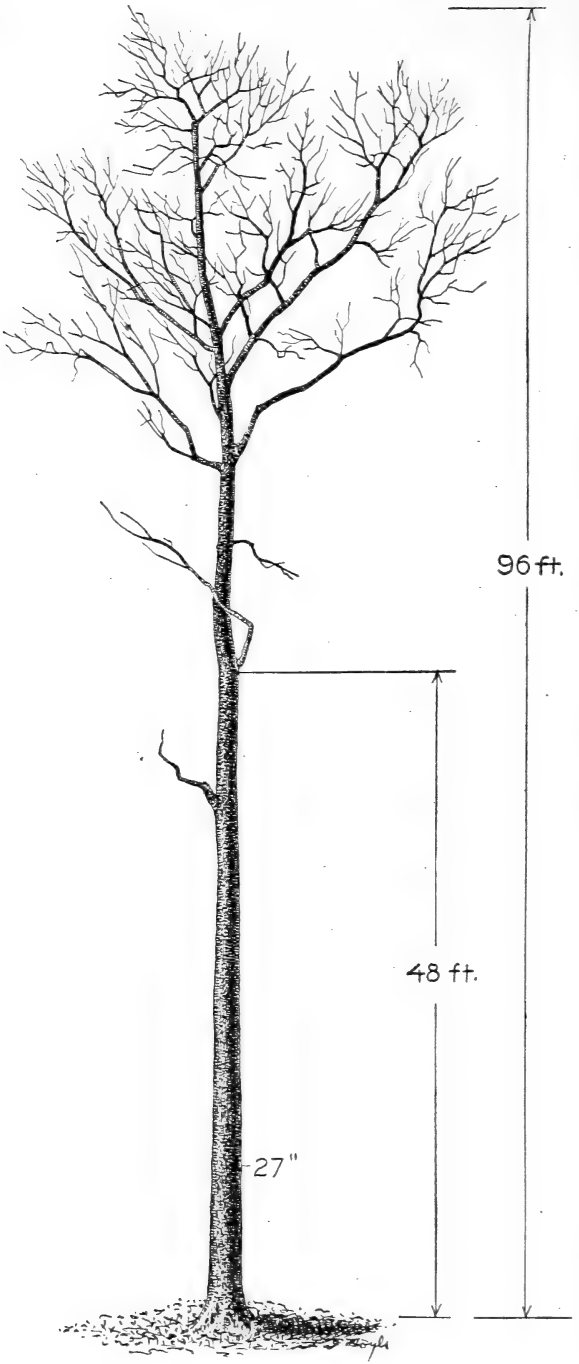

FIG. 3.—Forest-grown black walnut tree.

small end have been cut, and heights of 125 to 150 feet are on record, although to-day trees 100 feet tall are rare. The average tree that is cut at present contains about 15 feet of merchantable length.

When it has grown in the open, black walnut has the appearance of an orchard tree, with a short, clear bole and a round, spreading crown, which in summer exhibits a mass of beautiful foliage. In the winter the coarse branching habit and the large, dark twigs usually make it easy to identify the tree even at considerable distances, although young and abnormal trees may sometimes be mistaken for ash or hickory. In the forest a typical black-walnut tree presents a tall, clean bole of little taper up to the lowest branches. At this point the identity of the main trunk is frequently lost, and a few large limbs spread out to form a rounded crown at the level

of the forest canopy. The greater merchantable length, the more slender and more gradually tapering stems, and the smaller, more restricted crowns of forest-grown trees are in conspicuous contrast to the short, thick, rapidly tapering trunks and full crown of trees grown in the open. Of two neighboring trees measured in Indiana—one a field and the other a forest tree—the former, because of rapid taper and low branches, had only about 15 feet of merchantable length, but the latter had nearly 30 feet. Forest-grown trees near Fort Wayne, which measured from 30 to 35 inches in diameter, breast high, had from 64 to 72 feet of merchantable length.

It is very characteristic of walnut, both in the open and in the forest, for the main trunk to break up within a few feet of the lowest limbs into a number of large branches, no one of which appears to be the leader.

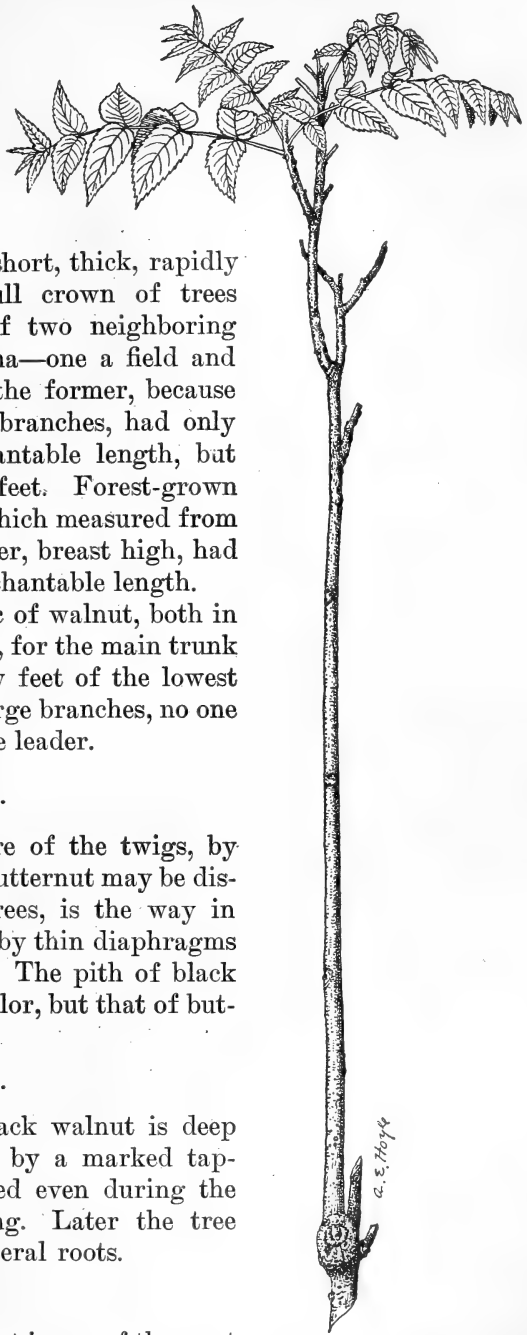

FIG. 4.—Black walnut seedling from a brushy site, at beginning of third year of growth.

TWIGS.

A characteristic feature of the twigs, by which black walnut and butternut may be distinguished from other trees, is the way in which the pith is divided by thin diaphragms into spaces or chambers. The pith of black walnut is of a pale buff color, but that of butternut is dark brown.

ROOTS.

The root system of black walnut is deep seated and characterized by a marked taproot. This is well defined even during the first year of the seedling. Later the tree throws out prominent lateral roots.

BARK.

The bark of black walnut is one of the most variable features of the tree, the differences being caused largely by different rates of

growth. The bark of a rapidly growing walnut tree is thin and reticulated in some places almost as much as the bark of ash; but, as a rule, the ridges and furrows are much larger and less regular, and the reticulation is not apparent. The color of the bark from inside to outside is always dark, being almost black when it is wet after a rain. On slow-growing old trees the bark becomes several inches thick and is broken up into irregular blocks by transverse cracks. This is especially true toward the southwestern limits of the walnut range in Texas, and there the color becomes lighter, being a reddish brown in some localities. The darker bark, as well as the greater straightness of bole and better general symmetry, are, however, usually sufficient when leaves and fruit are absent to distinguish walnut from butternut, or white walnut, as it is called in some sections.

LEAVES, FLOWERS, AND NUTS.

The leaves are pinnate, from 1 foot long on forest-grown trees to 2 feet on vigorous trees in the open, with from 15 to 23 leaflets, smooth and light shiny green above, paler and somewhat hairy below. The leaves closely resemble those of butternut and, to a less extent, those of ailanthus. In the midsummer the tree is very ornamental, but because the leaves are put out late the winter appearance continues for a relatively long time.

Flowers are borne at the same time the leaves begin to develop, the staminate or male flowers in catkins 3 to 5 inches long, and the pistillate or female flowers in inconspicuous clusters of two to five greenish flowers, on the ends of the branches. Only one or two of these pistillate flowers develop into nuts. The mature nuts are round to pear-shaped and 1½ to 2 inches in diameter outside the greenish fleshy husk that incloses them. The nut proper is nearly spherical, with many ridges roughening the surface. The value of the nuts as articles of sale is variable. Although in general the nuts have meats moderate in size and difficult to remove from the shell, the nuts from certain trees are exceptional both as to size and cracking qualities. The trees that provide these exceptional nuts are of value in developing special horticultural varieties.

SILVICAL CHARACTERISTICS.

SOIL AND MOISTURE REQUIREMENTS.

The requirement of black walnut for fertile, moist, but well-drained soils has already been discussed. This requirement should be kept in mind in selecting sites for the planting of walnut. In addition, because of the deep root system of walnut the subsoil underlying the planting site should be of a porous texture to a corresponding depth. A dry atmosphere does not seem greatly to

affect the growth of the tree, provided the soil conditions are suitable, for the development is good in the irrigated plantations that are scattered through the arid West, and the natural range of walnut extends in Texas into a region of relatively light rainfall. Its dependence upon good soil is more marked, however, in regions that have a relatively scant precipitation than it is in well-watered regions.

TOLERANCE OF SHADE.

Walnut is decidedly intolerant of shade, although its ability to endure shade varies with site and soil conditions and the age of the tree. During the first few years of its life it will bear considerable side shading, as is shown in occasional instances in which walnut was planted between rows of corn and grown successfully in combination with corn for two or three years. In mixed hardwood forests, where there is a lack of light, walnut reproduction is practically never found. It is found on the edges of the forest, along roadways and streams, and in other places where the continuity of the forest cover is broken. In the East, at least, it can come up successfully through brushy tangles of sassafras, sumac, rose, and raspberry bushes, and in between clumps of shrubby willows. In plantations the interlocking of the crowns soon causes a decided reduction of diameter growth; and, after the tree has attained a height of 30 to 40 feet, height growth is no longer stimulated by crowding, the effect of which is, rather, to cut down all increment. Suppressed trees in these conditions become stag-headed and put out water sprouts all the way up and down the trunk.

REPRODUCTION.

Black walnut reproduces both by seed and by sprout, the former means being very much the more common. The nut crops are usually generous and the percentage of fertility is high. Transportation of the seed to any distance, however, is practically dependent upon squirrels, and the greater part of the walnut reproduction is undoubtedly from nuts that are buried by squirrels in open grasslands adjoining forests. Started under these conditions, the seedlings receive the abundant light needed for their vigorous development. It is doubtful, in fact, whether the seedlings can successfully establish themselves from nuts that are left lying on the surface of the ground or are only lightly covered with fallen leaves. Of the nuts buried in the forest only a small proportion produces successful trees; most of the seedlings are eventually suppressed by the overhead shade unless they are fortunately located under some break in the forest canopy. This characteristic of walnut reproduction makes it appear likely that in many of the mixed stands containing walnut the walnut was the first to start, originating from nuts buried by squirrels in

open meadows and prairies, and that the associated species came in later beneath the walnut, after the latter had established forest conditions. The agency of squirrels in the establishment of walnut is probably responsible also for the frequency of practically even-aged groves of walnut. Of some even-aged stands, which started within the memory of living man, it is known that the small fields and hillsides they now occupy were seeded by squirrels in a single year. It is quite likely that this is the usual origin of even-aged stands that have sprung up without human action. Whether this is due to exceptionally heavy seed crops or to bad winters that killed off the squirrels before the nuts were dug up and eaten, or to short winters that did not force the squirrels to consume all their hoard, or to a combination of such circumstances, can not now be told.

Reproduction is remarkably rare in the greater part of the range of black walnut under conditions as they now prevail. Practically all walnut stands are grazed by cattle, that destroy the young seedlings, or, still worse, by hogs that eat the nuts. Consequently, no reproduction of walnut or anything else is taking place, and the stands are becoming grovelike, with open grassy floors. Even where grazing is excluded, however, walnut reproduction is not generally seen. This is difficult of explanation, but possibly it is linked with the effect of the settlement of the country on the number of squirrels and their habits.

In western Indiana profuse reproduction is occasionally found along the fence rows around fields containing old walnut trees, as well as scatteringly on open southern slopes of draws leading down to the Wabash River on both the Indiana and the Illinois sides. In some localities in Missouri young trees are characteristically scattered on open southern slopes near hollows that contain mature walnut. The growth on these open slopes, however, will be subnormal and the trees will be poor.

Conditions are much better farther eastward, and in such regions as southwestern and southeastern Pennsylvania, parts of West Virginia, northern Virginia, Maryland, northern Delaware, and western New Jersey reproduction is locally profuse. It is usually found along stream courses passing through agricultural lands, pastures, or woodlands, although by no means exclusively limited to such sites. Along roadsides, the edges of wood lots, fence rows, and, in fact, in almost any place where there is protection and sufficient light young walnut is likely to be found. In all this region the reproduction of walnut is rendered more certain than farther west, on account of the fact that the woodlands are not generally grazed here, while grazing is the rule in the Ohio Valley and westward. Even in this region of maximum reproduction, however, trees above 6 inches in diameter are seen much more frequently than seedlings.

Sprout reproduction occurs irregularly from stumps of small and moderate-sized trees cut, apparently, at any season of the year. The sprouts are usually numerous and come from the side of the stump somewhat above the root collar. During the first few years the sprouts usually grow tall, weak, and crooked, resembling those of cottonwood, especially if they are not in full light. The first season's growth probably continues until frost, which kills back the tops of the sprouts for as much as a foot. Unless there is plently of light, all the sprouts usually die in a few years. In the open, one or two or even three sprouts may persist and grow into fair-size trees. The original stump rots away, however, weakening the base of the sprout and infecting it with red butt rot. Sprout reproduction rarely produces a good tree of saw-log size. Certainly it is not to be considered seriously as a means of regenerating a stand.

DISEASES AND INJURIES.

FUNGI.

Black walnut is moderately free from tree diseases and is as resistant to injury as any of its associates. Red butt rot is found in a small percentage of trees, mostly old trees of northern growth, although it is very bad in parts of central Kentucky. As a rule the rot extends only a short distance up the tree, and "butting off" the lower 3 or 4 feet of a hollow tree will usually remove most of this defect. The "doty" zone that surrounds the advanced decomposition at the center is generally narrow; it is frequently possible, in fact, to saw boards within an inch of an open hollow before any discoloration appears.

A white top rot is found, limited almost entirely to southern logs, particularly from Oklahoma and Texas. Its presence is indicated by punky knots and occasionally by conks on the upper trunk. This rot extends a greater distance up and down the trunk than the red butt rot and is a much greater detriment to the logs, especially if they are to be used for sawing into lumber. A large log with a defective center might be made to furnish a large amount of first-class veneer, but could not to advantage be sawed into lumber.

INSECTS.

A tent caterpillar disfigures the foliage of many roadside trees and reduces the rate of their growth. It is reported, however, to be rare in forest-grown trees and groves, walnut being worst affected when it grows near cherry or apple trees. In ornamental trees the nests should be promptly burned. Except for this caterpillar, walnut is very free from insect pests.

GROWTH OF INDIVIDUAL TREES.

Walnut may be classed among the more rapid growing hardwoods. The fertility of the soil on which black walnut is usually found greatly facilitates the growth of the tree. The poorer the site, the slower are all phases of growth, in height, in diameter, and consequently in volume. Growth is also affected by the shade from adjacent trees, and this accounts for the characteristic differences in form. The rate of diameter growth, on soils of equal quality, depends normally upon the amount of foliage, and hence is slower in the small-crowned trees of the forest than in spreading-crowned open-grown trees. When the trees are suppressed by the shade of taller trees, diameter growth is greatly decreased.

HEIGHT GROWTH.

Table 2 gives an idea of the average height growth of black walnut in comparatively open, pure stands in central Indiana and Ohio. It should be accepted as applicable only to "grove walnut":

TABLE 2.—*Height growth of walnut in comparatively open stands in central Indiana and Ohio.*

Age.	Height.	Age.	Height.	Age.	Height.
Years.	*Feet.*	*Years.*	*Feet.*	*Years.*	*Feet.*
10	13	60	72	110	84
20	35	70	75	120	85
30	53	80	78	130	86
40	62	90	81	140	87
50	68	100	82	150	88

DIAMETER GROWTH.

In the course of this study diameter-growth measurements were made on 128 trees located at 16 places in 6 States. While the number of trees thus scattered is too small to afford reliable data, the average measurements shown in Table 3 will give a general idea of the average rate of diameter growth, breast high, of walnut under neither the best nor the poorest conditions:

TABLE 3.—*Breast-high diameter growth of walnut, based on measurements of 128 trees widely scattered.*[1]

Age.	Diameter, breast high.	Age.	Diameter, breast high.	Age.	Diameter, breast high.
Years.	*Inches.*	*Years.*	*Inches.*	*Years.*	*Inches.*
10	1.2	60	18.3	110	26.0
20	5.0	70	20.6	120	26.9
30	8.8	80	22.2	130	27.8
40	12.5	90	23.8	140	28.5
50	15.7	100	25.0	150	29.2

[1] Distribution of measurements: Indiana, 37 trees from 5 localities; Ohio, 75 trees, 3 localities; Illinois, 5 trees, 1 locality; Virginia, 5 trees, 1 locality; New Jersey, 7 trees, 1 locality; Missouri, 3 trees, 1 locality.

A few selected measurements are given below as illustrating the rate of diameter growth under specific conditions. It should be noted that they do not afford a safe basis for the comparison of different regions, since local differences in soil and stand may affect the rate of growth even more than a wide geographical separation:

(1) Near Indianapolis, Ind.; illustrating the difference in diameter growth of four trees that grew in the open and three that grew in the forest. The two situations were about one-quarter of a mile apart and the soil in both cases was deep, dark loam. The stand containing the forest-grown trees was open and parklike, as a result of cutting operations in late years. The other species in the stand were white ash, white oak, white elm, beech, sugar maple, hackberry, Kentucky coffee tree, and hornbeam. (Table 4, No. 1.)

(2) Fayette County, Ohio; a similar comparison of diameter growth in open fields or groves (45 trees) with that (of 13 trees) in dense stands of mixed hardwoods. The growth both in the open and in the forest is less than in the preceding case, probably due, in part, to less favorable soil and moisture conditions. (Table 4, No. 2.)

(3) Near Indianapolis, Ind.; eight trees that grew on a southwestern slope on the southern edge of a mixed hardwood stand of ash, elm, and white oak. (Table 4, No. 3.)

(4) Near Indianapolis, Ind.; six trees in a pure walnut grove on a flat meadow adjoining a mixed hardwood stand of oak, elm, ash, and hackberry. This stand is now somewhat dense and diameter growth is probably relatively low in late years. (Table 4, No. 4.)

(5) Near Fort Wayne, Ind.; five trees in a virgin mixed hardwood stand composed of white oak, elm, yellow poplar, and ash, with a slight amount of black walnut, located on a flat, with deep, rich, loamy soil of potential agricultural value. These trees are probably typical of the growth of the older walnut stands cut 40 years ago. (Table 4, No. 5.)

(6) Near Deer Park, Boone County, Mo.; three trees from a grove on bottom lands. (Table 4, No. 6.)

(7) Eleven butt logs laid aside for veneering at Indianapolis; of unknown source, but probably from Indiana. These are very choice logs—round, clear, of rapid growth, and indicative of the average maximum growth in this region. (Table 4, No. 7.)

(8) Two butt logs from Marshall, Ind. (Table 4, No. 8.)

(9) Five butt logs from Farmersburg, Ind. (Table No. 4, No. 9.)

(10) Four butt logs from Carmel, Ind. (Table 4, No. 10.)

(11) Seven butt logs from Shreve, Ohio. (Table 4, No. 11.)

(12) Six butt logs from Mount Gilead, Ohio; apparently came from a wheat field. (Table 4, No. 12.)

(13) Five butt logs at Farmville, Va.; probably forest grown in mixed hardwood stand on rich bottom land. (Table 4, No. 13.)

(14) Seven stumps, New Jersey. (Table 4, No. 14.)

(15) Two stumps near Cameron, Mo.; in a mixed hardwood stand on a northern exposure considerably above the stream bottom. Stump diameter, 17 inches, age 59 years. False rings were numerous. This growth was a little below the average.

(16) Three stumps on the Kansas River bottom lands near Lawrence, Kans. Averaged 28 inches in diameter, stump height, at 63 years; a very rapid growth.

(17) Three butt logs at Kaw City, Okla. Averaged 30 inches in diameter on the butt end at 88 years, which is also above the average. The logs came from the bottom lands of a tributary of the Arkansas River.

(18) Six stumps at Valley Falls, Kans., in the bottom lands of Delaware Creek. Averaged 25 inches in diameter, stump height, at 64 years; also above the average rate of growth.

(19) Five stumps in northern Delaware. Averaged 25 inches in diameter, stump height, at 94 years.

(20) One hundred 20-inch logs taken at random in Missouri, Iowa, and Kansas. Averaged 83 years of age at the top end. Logs of this size measured in Indiana and Ohio were 81 years of age. These figures would apparently indicate that the rate of diameter growth of walnut is about the same in the river-bottom woodlands of the prairie States as it is farther east.

TABLE 4.—*Examples of diameter growth of black walnut based on age described under the corresponding numbers on page 23.*

No.	Grown in—	Age (years).													
		10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
		Diameter at breastheight (inches).														
1	Forest	0.2	1.4	3.6	6.5	12.1	16.1	19.5	21.4							
	Open	1.4	5.4	10.2	14.8	18.8	22.3	24.6								
2	Forest	.6	3.1	5.4	8.0	10.8	12.9	15.2	17.2	19.1	20.8	22.4				
	Open	.6	3.1	5.4	8.5	11.8	15.0	17.8	20.5	22.8	24.9	26.6				
3	(1)	1.0	4.9	9.1	12.6	14.6	17.0	19.4	20.5							
4	(1)	1.7	7.0	12.6	16.1	18.8	20.6	22.0	23.3	23.5						
5	(1)	1.4	4.4	7.4	10.7	13.5	15.8	18.0	19.6	21.4	23.3	24.3	25.6	26.8	28.0	29.3
6	(1)	1.4	5.3	8.1	10.8	13.5	16.6	19.6								
7	(1)	2.4	6.4	10.7	15.0	18.3	21.4	24.0	26.3	28.0						
8	(1)	4.1	10.2	15.0	18.3	20.4										
9	(1)	.4	3.1	6.2	9.6	12.9	16.4	19.2	21.9	23.9						
10	(1)	2.0	6.4	10.6	14.6	17.6	21.0	24.0	25.7							
11	(1)	.9	4.4	7.4	11.8	16.0	20.5	24.3								
12	(1)	2.0	7.5	13.1	18.1	22.0	25.0									
13	(1)	1.4	5.8	10.2	14.0	17.4	20.0	22.3	24.2							
14	(1)	.8	7.1	13.0	17.5	20.6	23.4	24.0	24.6							

[1] See description on p. 23.

VOLUME GROWTH.

As the growth of a tree in volume depends upon the rate of growth in both diameter and height, it is more variable than either. A statement of the increment in board feet to be expected at the end of any period will consequently have little bearing upon any particular stand. In order, however, to present a general idea of the average volume growth of individual trees, Table 5 has been prepared. It indicates fairly well the volume growth in groves in the Ohio Valley, but does not apply to single trees or rows grown in the open, to forest-grown trees, particularly in the eastern part of the range, or to trees in artificial plantations. It is less applicable to groves in regions east or west of the Ohio Valley.

It is evident from this table that walnut may be grown most advantageously, from the standpoint of greatest continuous volume production, on long rotations, for the reason that both the average annual growth and the current annual growth continue to increase up

to 150 years at least. The age to which individual walnut trees could be best grown, from the standpoint of greatest volume production, is probably limited not so much by an ultimate decrease in the rate of volume growth as by the setting in of butt rot. The average age at which logs are cut at the present time is 80 or 90 years—a period at which the tree is making rapid growth.

TABLE 5.—*Volume growth of black walnut.*

Age.	Volume.	Average annual growth.	Current annual growth.[1]
Years.	*Board feet.*	*Board feet.*	*Board feet.*
50	48	1.0	...
60	100	1.7	5.2
70	150	2.1	5.0
80	200	2.5	5.0
90	260	2.9	6.0
100	320	3.2	6.0
110	380	3.5	6.0
120	440	3.7	6.0
130	505	3.9	6.5
140	565	4.0	6.0
150	635	4.1	7.0

[1] Average annual growth for each decade.

RELATION BETWEEN RATE OF GROWTH IN DIAMETER AND THE FORMATION OF SAPWOOD.

The thickness of the sapwood depends very largely upon the rapidity of growth, the trees which have grown most rapidly having the widest sapwood. For this reason thrifty young trees are more likely to have wide sapwood than old trees. Local differences in site, however, frequently modify the tendency to vary with rapidity of growth. Trees from certain regions are notoriously sappy, but from other places the percentage of black heart is uniformly high. The relation of rapidity of growth to thickness of sapwood is shown in Table 6, which is based on 124 logs from widely scattered points. Of those trees in which the rate of growth was about the average the sapwood contained from 12 to 14 annual growth rings.

TABLE 6.—*Thickness of sapwood.*[1]

Growth last decade.	Thickness of sapwood.	Years in sapwood.	Growth last decade.	Thickness of sapwood.	Years in sapwood.	Growth last decade.	Thickness of sapwood.	Years in sapwood.
Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*	
0.2	0.3	25	0.9	1.2	14	1.5	1.9	13
.3	.4	20	1.0	1.4	14	1.6	2.0	13
.4	.7	18	1.1	1.5	14	1.7	2.1	12
.5	.8	16	1.2	1.6	13	1.8	2.2	12
.6	.9	15	1.3	1.7	13	1.9	2.4	12
.7	1.0	14	1.4	1.8	13	2.0	2.5	12
.8	1.1	14						

[1] Based on measurements of 124 logs.

The light-colored sapwood of black walnut used to be considered more of a defect than it is now. It is the present practice of most manufacturers to subject their lumber to a steaming process as soon as it comes from the saw. This steaming turns the sapwood to the same color as the heartwood and renders it equally salable. The sapwood of posts decays very much faster than the heartwood, and this renders the use of round walnut posts decidedly unsatisfactory.

GROWTH OF STANDS (YIELD PER ACRE).

It is difficult to estimate the yield on an acreage basis, of a species that characteristically grows so scattered as black walnut does. However, the yields of pure, open, grovelike stands are given here as examples of what may be expected of natural stands under the best conditions.

The first example is that of a walnut stand covering an area of 2.5 acres, located in Decatur County, Ind. The growth is scattered somewhat regularly over the whole area, except near the middle, where an area of perhaps one-quarter of an acre was cleared around a gas well. The stand is entirely of walnut, apparently even-aged and about 50 years old. The forest floor is covered by a bluegrass sod and is grazed by hogs and cattle. Naturally under these circumstances there is no reproduction. The slope is slightly to the north, where a small permanent stream bounds the grove. The soil is a deep, rich loam, similar to that of the cultivated fields adjoining. (See Table 7.)

TABLE 7.

Diameter breast high.	Number of trees per acre.	Estimated yield per acre.	Diameter breast high.	Number of trees per acre.	Estimated yield per acre.
Inches.		*Board feet.*	*Inches.*		*Board feet.*
Below 8	10.0	.....	20 to 22	6.0	960
8 to 10	.8	.....	22 to 24	2.4	552
10 to 12	1.6	.....	24 to 26	1.6	512
12 to 14	6.8	.....	26 to 28	1.2	534
14 to 16	8.4	336	28 to 30	.4	246
16 to 18	7.1	497			
18 to 20	9.3	1,023	Total per acre	55.6	4,660

The larger merchantable trees on this area, together with some very large, short, "fence-corner" trees on another part of the farm—a total of 68 trees estimated to contain 15,000 board feet—were sold for $102.50 a thousand board feet on the stump. The above estimate of 4,660 board feet in this grove is believed to be low; but if it is accepted as it stands it gives a value of $477.65 an acre after 50 years, or an annual income of $9.55 an acre. In making comparisons it is imperative to remember that this stumpage price was exceptionally high even in a period of vastly inflated war prices. Before the war $40 a thousand would have been high.

The second example is that of a small grove of 48-year-old walnut mixed with younger trees of other species, in Hendricks County, Ind. The grove occupies six-tenths of an acre and is in a pasture adjoining a mixed hardwood stand of shagbark and bitternut hickory, white oak, elm, sycamore, and an occasional black walnut. This grove apparently illustrates the invasion of meadowland by the forest, in the progress of which walnut was the leader, the associated species being mostly young trees which came in after the walnut was established. The stand is still too small to show a large yield in board feet. (See Table 8.)

TABLE 8.

Diameter breast high.	Number of trees per acre.		Walnut yield per acre.
	Walnut.	Other species.[1]	
Inches.			*Board feet.*
Below 8	5.2	15.5	.....
8 to 10	8.6	3.4	.....
10 to 12	6.9	1.7	.....
12 to 14	10.4	10.4	.....
14 to 16	8.6	.....	344
16 to 18	6.9	.....	483
18 to 20	1.7	.....	187
Total	48.3	31.0	1,014

[1] Elm, shagbark, white oak, bitternut, and hackberry, in the order of abundance.

Another stand of much the same form was found in Hendricks County, Ind., growing under similar conditions in a pastured area. Originally this stand fringed a mixed hardwood stand very similar to the previous example, but the timber has been largely removed. This walnut stand is not quite pure, but has a slight admixture of hickory, oak, and Kentucky coffeetree, along with seedlings of ash and Kentucky coffeetree. There is an excellent sod, and the area is grazed by cattle. The walnut stand occupies half an acre. The age of the stand is not known, but it is evident that it is still immature and will have a very much greater value in 20 or 30 years. (See Table 9.)

Another walnut grove in Jefferson County, Kans., shows that stands of this kind are by no means limited to the Ohio Valley. This stand, which is about 60 years old, and nearly even aged, is located on the bottom lands of Cedar Creek, on an area of about 15 acres, bounded on the south by Cedar Creek and on the north by corn land. This land is subject to overflow for a few days in exceptional years, but usually it is above high water. The soil is a deep, dark loam, which gives excellent corn yields in the adjoining fields. The stand has not been grazed, and there is a considerable amount of

undergrowth of young elm, hackberry, and *Crataegus*, but not of walnut.

TABLE 9.

Diameter breast high.	Number of trees per acre.		Yield per acre of walnut.
	Walnut.	Other species.[1]	
Inches.			*Board feet.*
Below 8	4	2	----------
8 to 10	6	----------	----------
10 to 12	12	2	----------
12 to 14	4	4	----------
14 to 16	2	2	80
16 to 18	8	----------	560
18 to 20	8	2	880
20 to 22	0	----------	----------
22 to 24	1	----------	230
24 to 26	----------	----------	----------
26 to 28	----------	----------	----------
28 to 30	----------	----------	----------
30 to 32	----------	2	----------
Total	45	14	1,750

[1] Shagbark hickory, Kentucky coffeetree, and white oak, in order of abundance. The two trees 30 to 32 inches in diameter were white oak.

Of the trees over 8 inches in diameter, breast high, the stand contains, on an average, 23 merchantable walnut trees to the acre, 38 unmerchantable walnuts, and 8 other trees (hackberry, burr oak, and Kentucky coffeetree). The merchantable trees average 2.45 logs to the tree, or 24.5 feet of merchantable length. The average log contains 55 board feet. Each tree, therefore, averages 135 board feet, and the merchantable stand to the acre is 3,275 board feet. These figures are based on 208 logs that had been cut and were actually scaled. This stand was too small to show maximum productivity, but it indicates what may actually be secured in 60 years in western river-bottom lands.

MEASURING LOGS AND ESTIMATING STANDING TIMBER.

MEASURING LOGS.

The Doyle rule (Table 10) is in general use for scaling walnut logs, and has been used in this bulletin in all computations involving board feet. This rule penalizes small logs very heavily, and does not at all represent the amount that can actually be sawed from them. With the present run of logs averaging 70 to 80 feet to the log, 1,000 feet scaled in the log by the Doyle rule will cut about 1,400 feet of lumber. In logs about 25 inches in diameter the Doyle scale represents closely the actual amount that can be cut in walnut of good quality.

ESTIMATING STANDING TIMBER.

Because of the high value, scattered occurrence, and variation in form, of black-walnut trees, estimates of their volume are now made, not by the "cruising" methods commonly practiced in the timber

TABLE 10.—*The Doyle log rule.*

Diameter in inches.	Length in feet.										
	6	7	8	9	10	11	12	13	14	15	16
	Board feet.										
6	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4
7	3.4	3.9	4.5	5.1	5.6	6.2	6.8	7.3	7.9	8.4	9
8	6	7	8	9	10	11	12	13	14	15	16
9	9	11	12	14	16	17	19	20	22	23	25
10	13	16	18	20	22	25	27	29	31	34	36
11	18	21	24	28	31	34	37	40	43	46	49
12	24	28	32	36	40	44	48	52	56	60	64
13	30	35	40	46	51	56	61	66	71	76	81
14	37	44	50	56	62	69	75	81	87	94	100
15	45	53	60	68	76	83	91	98	106	113	121
16	54	63	72	81	90	99	108	117	126	135	144
17	63	74	84	95	106	116	127	137	148	158	169
18	73	86	98	110	122	135	147	159	171	184	196
19	84	98	112	127	141	155	169	183	197	211	225
20	96	112	128	144	160	176	192	208	224	240	256
21	108	126	144	163	181	199	217	235	253	271	289
22	121	142	162	182	202	223	243	263	283	304	324
23	135	158	180	203	226	248	271	293	316	338	361
24	150	175	200	225	250	275	300	325	350	375	400
25	165	193	220	248	276	303	331	358	386	413	441
26	181	212	242	272	302	333	363	393	423	454	484
27	198	231	264	298	331	364	397	430	463	496	529
28	216	252	288	324	360	396	432	468	504	540	576
29	234	273	312	352	391	430	469	508	547	586	625
30	253	296	338	380	422	465	507	549	591	634	676
31	273	319	364	410	456	501	547	592	638	683	729
32	294	343	392	441	490	539	588	637	686	735	784
33	315	368	420	473	526	578	631	683	736	788	841
34	337	394	450	506	562	619	675	731	787	844	900
35	360	420	480	541	601	661	721	781	841	901	961
36	384	448	512	576	640	704	768	832	896	960	1,024
37	408	476	544	613	681	749	817	885	953	1,021	1,089
38	433	506	578	650	722	795	867	939	1,011	1,084	1,156
39	459	536	612	689	766	842	919	995	1,072	1,148	1,225
40	486	567	648	729	810	891	972	1,053	1,134	1,215	1,296

forests, in which all or many of the species are to be logged together, but by the separate examination of each merchantable tree. The usual practice is to estimate first the length and small-end diameter inside the bark of each log in the tree, and then to find the contents of the logs in board feet by the Doyle rule. To estimate closely the length and taper of the logs and their diameters inside the bark requires a practiced eye and a knowledge of bark characteristics, in order that the thickness may be gauged from appearances with relative accuracy. In most merchantable logs the bark averages from 1 to 1½ inches in thickness, as shown in Table 11.

TABLE 11.—*Thickness of bark, in inches, on logs of different diameters.*[1]

Diameter of log.	Bark thickness.	Diameter of log.	Bark thickness.	Diameter of log.	Bark thickness.
6	0.5	15	1.1	24	1.3
7	.5	16	1.2	25	1.4
8	.6	17	1.2	26	1.4
9	.7	18	1.3	27	1.4
10	.8	19	1.3	28	1.4
11	.9	20	1.3	29	1.4
12	1.0	21	1.3	30	1.4
13	1.0	22	1.3		
14	1.1	23	1.3		

[1] Based on 291 logs mostly from Ohio and Indiana.

In selling walnut on the stump the owner should accompany the buyer, who is usually an experienced walnut cruiser, and with him estimate the length and small diameter of each log that will be cut, keeping a detailed memorandum of the scale and the sizes agreed upon.

The average form and development of trees of different diameters at breastheight are shown in Table 12, which may be used as a rough volume table for average trees, particularly if they have been grown in groves or wood lots. The trees used as a basis grew in Ohio and Indiana, but the form is probably very much the same throughout the range of walnut, except where conditions are very unusual, as around the outer limits of the range, particularly toward the west and southwest.

TABLE 12.—*Form and volume of walnut trees of different diameters, breast high.*

Diameter breast high (inches).	Distance above ground (feet).									Total height (feet).	Merchantable length[2] (feet).	Volume[3] (board feet).
	1[1]	10	20	30	40	50	60	70	80			
	Diameter inside bark (inches).											
1	2.6	0.2	.....	.....	.....	.....	.....	.....	.....	11	.....	.....
2	3.5	1.0	.....	.....	.....	.....	.....	.....	.....	16	.....	.....
3	4.3	1.7	0.1	.....	.....	.....	.....	.....	.....	22	.....	.....
4	5.1	2.4	.8	.....	.....	.....	.....	.....	.....	29	.....	.....
5	6.1	3.0	1.5	.....	.....	.....	.....	.....	.....	35	.....	.....
6	7.1	3.7	2.2	1.1	0.1	.....	.....	.....	.....	40	.....	.....
7	8.0	4.5	2.9	1.7	.6	.....	.....	.....	.....	45	.....	.....
8	9.0	5.4	3.6	2.3	1.2	.....	.....	.....	.....	50	.....	.....
9	9.9	6.2	4.3	3.0	1.7	0.4	.....	.....	.....	53	.....	.....
10	10.8	7.0	5.0	3.6	2.2	.9	.....	.....	.....	57	.....	.....
11	11.7	7.8	5.7	4.2	2.7	1.3	.....	.....	.....	59	.....	.....
12	12.6	8.6	6.4	4.8	3.3	1.8	0.1	.....	.....	61	.....	.....
13	13.5	9.5	7.2	5.4	3.8	2.3	.5	.....	.....	63	8	18
14	14.5	10.3	8.0	6.0	4.4	2.8	.9	.....	.....	64	11	27
15	15.4	11.1	8.7	6.7	5.0	3.3	1.3	.....	.....	66	13	40
16	16.4	11.9	9.5	7.3	5.5	3.8	1.8	.....	.....	68	17	52
17	17.4	12.8	10.2	8.0	6.2	4.4	2.3	.....	.....	70	21	70
18	18.4	13.7	11.0	8.7	6.9	4.9	2.7	0.1	.....	71	25	88
19	19.4	14.6	11.8	9.3	7.5	5.5	3.3	.5	.....	73	28	110
20	20.5	15.5	12.6	10.0	8.1	6.0	3.8	1.0	.....	74	31	132
21	21.6	16.4	13.4	10.7	8.8	6.6	4.3	1.5	.....	76	34	160
22	22.7	17.4	14.2	11.5	9.3	7.2	4.9	2.0	.....	78	37	190
23	23.4	18.5	15.0	12.2	10.1	7.8	5.5	2.5	.....	79	40	230
24	25.1	19.5	15.9	13.0	10.8	8.5	6.0	3.0	0.3	81	43	270
25	26.6	20.6	16.7	13.8	11.5	9.6	6.6	3.5	.7	82	46	320
26	28.1	21.8	17.6	14.6	12.3	9.8	7.2	4.1	1.2	84	49	380
27	30.0	22.8	18.5	15.4	13.0	10.5	7.8	4.7	1.7	85	52	445
28	31.8	23.8	19.4	16.2	13.7	11.2	8.4	5.3	2.2	87	54	520
29	33.9	24.9	20.2	17.1	14.4	11.9	9.0	6.0	2.7	88	57	615
30	36.0	26.0	21.1	18.0	15.2	12.6	9.7	6.6	3.3	90	59	720

[1] Stump height assumed to be 1 foot.
[2] Merchantable length to a top diameter (inside bark) of 10 inches.
[3] Figured by Doyle rule, values curved.

Short-cut methods of approximating the contents of standing trees are often of use, as in the case of preliminary correspondence between buyers and prospective sellers. According to a very satisfactory method used by one firm in gaining a general impression of the amount, the owner is requested to send in a list of all trees offered for sale, giving the girth of each at 4½ feet above the ground and its length to the first living branch. The girth divided by 4 will give

approximately the diameter of the first 12-foot log inside the bark at the small end and the clear length will indicate whether the tree is a field or a forest grown walnut and will show to a certain degree how many logs may be expected. The size of the upper logs may then be estimated on the basis of the butt log. This method is simple and well adapted for the use of the walnut owner who wants to know approximately how much walnut he has.

WALNUT PLANTATIONS.

Walnut has always been a popular tree for planting on account of its attractive appearance, the value of its wood, the production of nuts, and the ease with which it may be propagated. Walnut has consequently been planted in every State in the country as single shade trees, as windbreaks, as open, orchardlike stands planted for nuts, or as closely planted stands for log timber. The last are found chiefly in the prairie regions from Ohio westward. There are 126 stands on record in Iowa alone, which is probably the leading State in this respect. Most of the plantations of this kind were established in the period of the great popularity of the wood, from the close of the Civil War to 1890, although at least one, in Missouri, dated back to 1836, and another, in Illinois, is said to have been planted in 1823. These plantations have improved the general appearance of the farms and have served excellently as shady groves for cattle.

FACTORS AFFECTING THE SUCCESS OF PLANTATIONS.

Many owners take special pride in their walnut plantations and maintain that these add to the market value of the farm. In most cases this is undoubtedly true, and the reasons are those mentioned above; but, because of lack of management, unfortunately many walnut plantations have not been successful as producers of valuable wood. The following table shows the average breast-high diameter growth in plantations, in comparison with the average for the natural stands of block walnut measured (Table 13), and with the slowest growth observed in a natural stand (see description of forest-grown stand in Fayette County, Ohio, on p. 23). The figures for growth in plantations are based upon measurements of 90 plantations.

This comparison of artificial with natural stands is not very favorable to the artificial. After the planted trees reach 50 years of age the growth is slower than that of the slowest observed in natural stands. Furthermore, the mediocre quality of the planted but unmanaged trees was in marked contrast to the clean, straight, very tall boles of the forest-grown trees. Two reasons may be assigned

for this prevailing inferiority of walnut plantations—either there was a poor choice of planting sites or there was wrong management of the planted stands, or both.

TABLE 13.—*Diameter growth in plantations, in comparison with average and slow growth in natural stands.*

Age (years).	Diameter, breast high (inches).		
	In plantations.	In natural stands—	
		Of average growth.	Of slow growth.
10	2.0	1.2	0.6
20	5.2	5.0	3.1
30	7.4	8.8	5.4
40	9.2	12.5	8.0
50	10.9	15.7	10.8
60	12.3	18.3	12.9
70	13.4	20.6	15.2
80	14.4	22.2	17.2

CHOICE OF PLANTING SITES.

The plantations of walnut in the prairie regions were quite naturally started in the situations in which the owners most needed trees; that is, on the treeless uplands or, occasionally, in recent years, on parts of cleared bottom lands. The sites selected were only rarely those which supported tree growth at the time of the settlement. The soil quality of these sites may be excellent, but the moisture present in the soil during the summer is insufficient for the flourishing growth of walnut.

As has been pointed out on pages 4 and 18, walnut needs for good growth a deep, fertile soil, both well watered and well drained, permitting the free movement of soil moisture and, at the same time, the access of air to the roots. These qualities are the more necessary the less favorable the climatic conditions, especially the precipitation. From Indiana westward soils suitable for planting are to be found principally in bottom lands, but bottom-land soils are in fact to be preferred even in the East. Swampy areas and places where cottonwood, willows, sycamore, or river birch form, or have formed, the chief growth will usually prove unsuited to walnut, though areas subject to floods for short periods, in which the backwater does not stand long in the depression, may form excellent sites. If the soil is a sterile sand, or if hardpan exists not far beneath the surface, as in parts of the Lake States, walnut can not be grown satisfactorily, even in the most favorable climate.

In the East, with its larger amount and better distribution of rainfall, much more freedom in the selection of planting sites is possible than in the prairie regions or in the Lake States. In the limestone regions of Tennessee, Kentucky, West Virginia, and the northeastern part of the range in general, cut-over lands and even rocky hillsides,

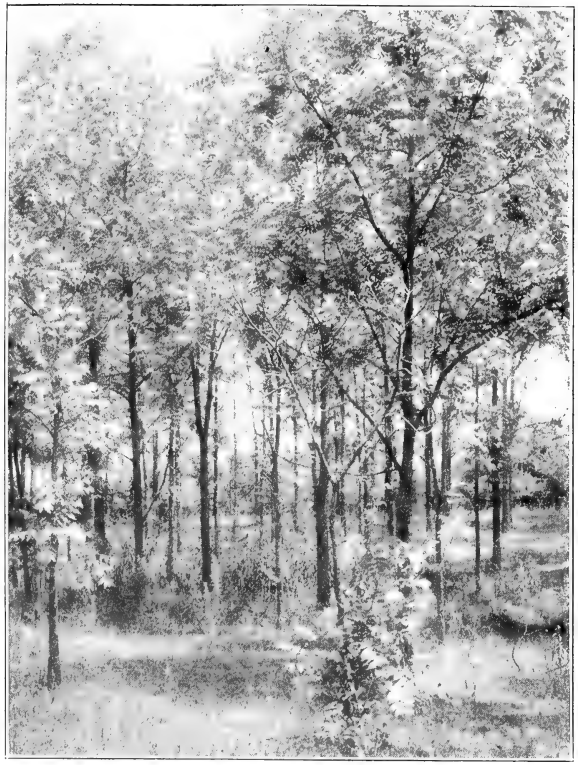

FIG. 1.—POOR SOIL.

FIG. 2.—GOOD SOIL.

EFFECT OF SOIL QUALITY IN AN INDIANA BLACK-WALNUT PLANTATION.

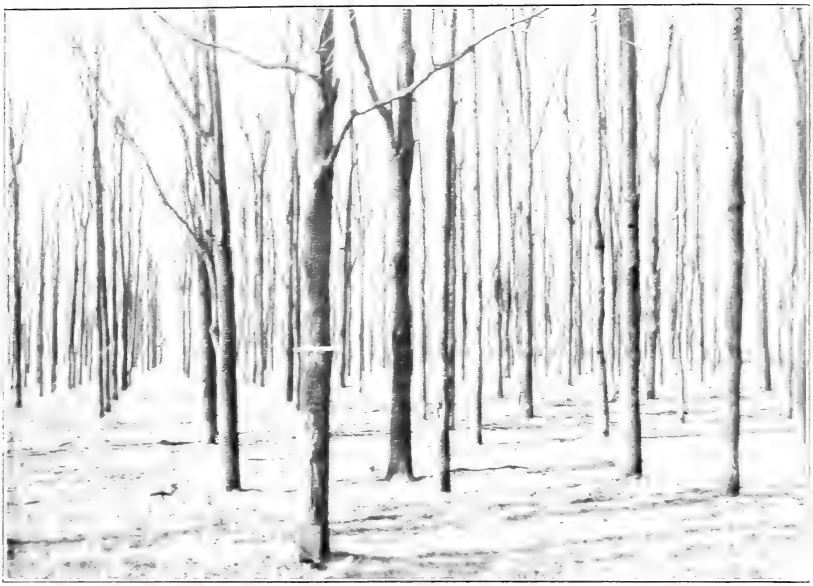

FIG. 1.—PLANTATION OF BLACK WALNUT IN HOWARD COUNTY, IND. THE TREES ARE CLOSELY SPACED, AND THOSE STANDING ALONG THE OUTER EDGE MEASURED LARGER IN DIAMETER THAN THOSE INSIDE.

FIG. 2.—BLACK-WALNUT PLANTATION, SHOWING CLEAN STEMS MADE BY HIGH PRUNING.

if erosion is not actively taking place, are promising sites for the successful growth of walnut. Similarly, the level, rolling country of southeastern New York, eastern Pennsylvania, and New Jersey west of the sandy parts, where the soils are deep, present favorable sites for walnut. Western Maryland and the Shenandoah Valley of Virginia are generally well suited, but eastward to the coast the soils are usually not adapted, although occasional sites on river bottoms or rich flats are excellent and have produced walnut shade trees of large size. In North Carolina, South Carolina, and northern Georgia, except in the mountain region, it is doubtful if the climatic conditions are best for walnut. The species range almost to the Gulf and has been planted as an ornamental tree in Florida, where phenomenal crops of nuts are reported; but often in this region the tree is poor in quality and becomes defective at an early age. The planting of walnut for its wood in most of North and South Carolina, Georgia, Alabama, and Louisiana is problematical, because there has been no experience with actual plantations in that region.

The best criterion for determining a planting site, either in the East or West, is whether walnut grew on the site naturally and made a good development. If it did, planting is safe; if it did not, the planting may be successful with good management, but there is an element of uncertainty involved.

The soil needed for the most satisfactory production of merchantable stands of walnut is nearly everywhere the best agricultural soil. Placed on a strictly economical basis, there is little argument for growing walnut for wood production on these soils. Tillotson[1] shows the net annual yield for 12 plantations from 12 to 42 years of age scattered from Indiana to Iowa. The best stand shows an annual income of 91 cents an acre; the poorest, a loss of $1.50 an acre annually, while the average plantation shows a loss embodying failure to pay taxes and interest charges on the expense of establishment. In the States in which walnut is of chief importance the gross income from farm crops amounts annually to about $15 an acre. Excluding all interest charges, it would be necessary to have about 65 thousand feet, board measure, to the acre at the end of 75 years in order to yield an equal gross annual income. According to the most optimistic estimates the amount would hardly be 20 per cent of this. There is no point in giving up good agricultural land that can be used as such to the growing of walnut for wood only.

MANAGEMENT OF PLANTED STANDS.

Walnut is intolerant of shade, and this is an important item in its management, disregard of which is one of the causes of the unsatis-

[1] "Forest Planting in Eastern United States," by C. R. Tillotson, Bulletin 153, United States Department of Agriculture, p. 31.

factory development of plantations. It affects the crown density and directly limits the number of trees to the acre under which the proper growing conditions may be maintained and the best material produced. The number of trees to the acre required to maintain a continuous crown cover is, of course, largest in the early history of a plantation and decreases with age, either naturally, through the crowding out of the less rapid growing individuals, or under management through their removal in thinnings. In the case of walnut close spacing (see "Spacing," p. 42) at the start is more practicable than with many other species, because of the relatively low cost of nuts and planting. This close spacing tends to reduce, although it can not always prevent, the profuse branching of the trees at a height of about 6 feet. When, however, the crowns commence to crowd each other badly, some beginning to take the lead and others to fall behind, it is poor economy to maintain such a density, and thinnings become imperative. Left to themselves, these even-aged plantations develop so uniformly that the dominant trees do not much exceed their lesser neighbors in height, the thrift of the whole stand is lowered by mutual suppression, and the stand is in a condition of stagnation. Ultimately, the crowns become very much reduced and stag headed, and water sprouts come out profusely on the trunks. These water sprouts grow slowly until the tree dies or is released by the death of neighboring trees; whereupon the sprouts take a new lease of life, and the tree develops into a topless branchy stub of no use for any purpose.

The combined effects of poorly chosen site and overcrowding are shown in a plantation in Jackson County, Mo. Although the plantation is 82 years old, few of the trees are merchantable. The stand is situated on a hilltop, which, in this western region, is too dry for walnut; consequently, the trees of the outermost row, exposed to full light on one side, have poor development, branch low, and are practically worthless. The effects of overcrowding upon the condition both of the trees inside the plantation and of those in the outer row may be summarized as in Table 14.

TABLE 14.

	Average diameter breast high.	Percentage of total number of trees.		
		Healthy.	Water spouted.	Decayed.
	Inches.			
Outer row	17.1	65	18	17
Inner trees	12.7	34	63	3

In a plantation 31 years old in Howard County, Ind. (Pl. V, fig. 1), the outer trees averaged 8.3 inches in diameter, breast high, and the inner trees only 7.4 inches. There were 342 trees to the acre in this plantation, although experience indicates that 300 to the acre is full stocking at this size. Natural groves seldom contain over 60 trees to the acre at 60 years of age.

Pruning.—Walnut trees may be pruned with profit, the object being to obtain clean, straight boles. Logs from such trees are distinctly more valuable. Before the war knotty logs usually brought $20 to $25 a thousand board feet, f. o. b. cars, shipping point, regardless of size, and smooth logs were paid for on a sliding scale of prices, the lowest of which was better than the flat price for cull logs. In average logs the difference was about $20 a thousand board feet. If pruning will double the value of a log, it is certainly a paying proposition. The spreading tendency of the walnut tree and its intolerance of shade make pruning to some extent necessary even in the best-managed stands. Limbs that support essential parts of the crown should not be taken; but smaller branches and low limbs that will ultimately be crowded out should be cut to hasten the natural process and give more clear wood in the log. The pruning should be flush with the trunk, and care should be taken not to injure the trunk. The saw is ordinarily the best instrument to use. The first cut should be from beneath, and should sever bark and wood sufficiently to prevent peeling of the trunk when the branch drops. A second cut made from above then severs the branch. It is well to prevent the subsequent infection of the wound with the germs of decay by painting it with tar or with a good water-resisting paint.

PROBABLE YIELDS FROM PLANTATIONS.

As there are few plantations in this country that have grown up under ideal soil conditions and have been properly tended, it is impossible to judge future yields of logs from actual examples of plantations, and all natural stands are spaced so irregularly that they do not represent maximum productivity any more than do the overcrowded plantations. The growth in value of individual trees may be estimated, however, on the basis of the prices current in the year 1918. Table 15 shows the values of trees of different sizes delivered at the railroad. Except when they were close to shipping points, it was not profitable in 1918 to cut trees under 17 inches in diameter.

It is apparent from Table 15 that the value of walnut increases rapidly with age, partly because it holds up its increment well, but more on account of the sliding scale of prices for logs that is everywhere in vogue for this species, and which places a decided premium

on large logs. Trees in plantations, therefore, should be grown as long as they appear sound and healthy. Of course, it is impossible to tell at this time what scale of log prices will be used 150 years hence, but, nevertheless, the plantation should be managed with a long rotation in mind.

TABLE 15.—*Value of individual trees.*[1]

Diameter breast thigh.	Volume board feet.	Value at railroad.[2]	Age.	Diameter breast thigh.	Volume board feet.	Value at railroad.[2]	Age.
Inches.			*Years.*	*Inches.*			*Years.*
13	18	$0.36	42	22	190	$8.20	79
14	27	.54	45	23	230	10.80	85
15	40	.75	48	24	270	13.80	92
16	52	1.00	51	25	320	17.30	100
17	70	1.70	55	26	380	21.50	110
18	88	2.40	59	27	445	26.50	121
19	110	3.40	63	28	520	32.20	132
20	132	4.70	68	29	615	39.90	147
21	160	6.10	73	30	720	49.00	.....

[1] This table applies to individual trees in groves or open woodlands and not to trees grown singly in the open field. The prices were those current in the year 1918.

[2] As the stumpage price is so variable, depending upon the length of haul, the value of the trees delivered at the railroad is the most constant figure that may be given. Stumpage value may be figured by subtracting cutting and hauling expenses from the value of the logs delivered.

The number of trees on a well-managed plantation will at all times show the maximum that can be grown to the best advantage. The reduction from year to year will be accomplished by frequent thinnings and will not be left to the processes of nature that lead to excessive mutual suppression and to stagnation of growth. Such a plantation on good soil should yield logs somewhat as shown in Table 16. The calculation is believed to be conservative for the Ohio Valley and northeastern region, but possibly it is somewhat high for the trans-Mississippi States, where height growth is not generally so good and where merchantable length is, therefore, somewhat less.

TABLE 16.—*Possible yield of black walnut plantations.*

Age (years).	Average diameter breast high (inches).	Number of trees per acre.[1]	Board feet per acre.	Value per acre.[2]
10	1.2	2,700	.....	.....
20	5.0	700	.....	.....
30	8.8	280	.....	.....
40	12.5	160	.....	.....
50	15.7	100	4,800	$83.00
60	18.3	85	8,500	229.50
70	20.6	70	10,500	387.80
80	22.2	65	13,000	566.80
90	23.8	55	14,300	726.00
100	25.0	50	16,000	865.00

[1] Derived from Table 1, p. 2, Farmers Bulletin 711, "The Care and Improvement of the Woodlot," by C. R. Tillotson.

[2] Based on the value of logs delivered at the railroad and not on the value of the stumpage, as the latter is too largely conditioned by cutting and hauling expense.

If a plantation, initiated with wider spacing, is left to grow into merchantable timber, the production will be less than that indicated

above. In the first place, the height and merchantable length will be less, on account of the lack of close spacing in youth; in the second place, the clear length will be less and the quality poorer and, therefore, the prices will be less; and, in the third place, after about 30 or 40 years the diameter growth will be smaller, as the trees will have begun to crowd each other, unless they were planted very far apart. With an initial spacing of 6 by 16 feet, making about 450 trees to the acre, a thinning will be necessary in about 30 years. Even if the stand is not thinned at this time, the taller and more thrifty trees will probably have sufficient light to become merchantable, although they will be inferior to trees that have had the proper care all their life.

Open-grown trees or orchards planted for the sake of the nuts will naturally have a more rapid growth in diameter, but will have less clear length. The value of such open-grown stands will manifestly be incidental to the production of nuts (see "Production of Nuts," p. 37).

In the West, black walnut is planted to some extent on irrigated land for windbreak and ornamental purposes as well as for the yield of nuts. The logs are not likely to find a very ready sale, as the freight rates to all mills that specialize on walnut are excessively high, amounting to $50 a thousand board feet or more; and it is unlikely that the amount of timber in any one place will justify cutting by local mills. Growth under these conditions is apparently very much the same as in the prairie States.

Two plantations offer the comparisons shown in Table 17, one being a wide-spaced plantation in eastern Illinois, in which the trees are 6 by 16 feet apart, and the other a windbreak near Ogden, Utah. The plantation in Illinois is located on a rise several hundred yards from a stream, and, as there never was any natural tree growth on the area, it is possible that the site is too dry for walnut. The soil is rich black prairie loam. The spacing of the trees is very wide, and there is little difference in diameter between marginal trees and those within the stand. The plantation in Utah is situated along an irrigating ditch, in which water is flowing during practically the entire growing season.

TABLE 17.

	Age (years).	Average height (feet).	Diameter, breast high (inches).		
			Average.	Largest.	Smallest.
Illinois	51	55	12.8	21.6	7.0
Utah	52	55	12.1	23.2	3.5

PRODUCTION OF NUTS.

Although growing walnut for the sake of the nuts produced is a matter of horticulture rather than of forestry, it is necessary to take this source of income into consideration in dealing with this species

as a wood producer. It is, of course, impossible to get a maximum yield of walnuts and of wood at the same time, because the former demands a wide spacing that will give low wide-spreading crowns exposed to full sunlight, and the latter calls for a closer spacing with consequent limitation of the individual crowns and of the amount of fruit produced. In the average grove planted for general utility as scattered trees or small clumps, the walnuts will be a by-product of some value, either for family use or for sale. In some sections the growing of trees for the nuts only may be more profitable, and the logs produced in small numbers will be of secondary importance. Table 18 contains the statistics of the Thirteenth Census (1910) upon the production of walnuts.

TABLE 18.—*Production of walnuts, by States, according to the Thirteenth Census (1910).*

State.	Bearing trees.	Under bearing size.	Bearing trees per farm reporting.	Nuts per bearing tree.	Price per pound.	Income per tree.
				Pounds.	*Cents.*	*Cents.*
Alabama	3,228	1,753	3.1	48.8	2.2	107.5
Arizona[1]	(2)					
Arkansas	9,104	5,640	9.2	56.4	1.5	84.5
California	6,582	7,905	27.2	24.2	1.6	37.5
Colorado[1]	(2)					
Connecticut	3,188	2,636	12.6	14.2	4.1	58.2
Delaware	890	554	3.4	39.5	1.6	63.2
Florida	470	2,855	2.5	90.7	1.8	163.3
Georgia	6,850	2,258	3.8	62.4	2.1	131.0
Idaho[1]	(2)					
Illinois	44,159	24,698	24.7	12.0	1.4	16.8
Indiana	11,848	4,822	12.9	31.9	1.2	38.2
Iowa	125,194	24,277	31.7	9.1	1.8	16.4
Kansas	113,537	8,619	60.6	3.3	1.6	4.8
Kentucky	14,521	2,360	15.8	54.8	1.4	76.7
Louisiana	616	655	4.0	88.7	1.8	159.5
Maine	231	63	7.2	6.9	3.1	21.4
Maryland	5,375	1,522	5.3	51.2	1.1	56.4
Massachusetts	1,910	434	6.8	20.9	3.0	62.7
Michigan	16,105	3,520	6.7	33.9	1.4	16.8
Minnesota	3,459	922	21.9	24.9	1.9	47.3
Mississippi	2,914	2,391	3.6	52.0	2.4	124.8
Missouri	85,330	15,199	21.6	28.7	1.0	28.7
Montana[1]	(2)					
Nebraska	78,296	36,526	50.4	4.9	2.3	11.3
Nevada[1]	(2)					
New Hampshire	1,518	208	9.6	8.8	2.8	24.6
New Jersey	4,168	804	3.9	36.3	1.8	65.4
New Mexico[1]	(2)					
New York	19,782	2,815	7.0	23.6	2.5	59.0
North Carolina	19,570	9,180	5.0	55.3	1.5	83.0
North Dakota[1]	(2)					
Ohio	8,693	3,399	9.2	40.8	1.3	53.0
Oklahoma	21,412	7,204	45.6	4.4	1.7	7.5
Oregon	2,024	3,405	7.8	34.2	1.9	65.0
Pennsylvania	65,075	22,193	4.7	33.3	1.8	60.0
Rhode Island[1]	(2)					
South Carolina	3,662	2,258	3.7	50.6	2.0	101.2
South Dakota	16,726	10,219	54.0	4.4	2.0	8.8
Tennessee	18,225	3,536	14.2	38.9	1.3	50.5
Texas	1,820	1,206	6.5	30.5	1.8	55.0
Utah[3]	(4)					
Vermont	1,704	253	15.5	19.3	2.2	42.5
Virginia	23,049	9,173	8.9	26.1	1.6	41.7
Washington	1,427	601	13.7	30.5	1.6	48.6
West Virginia	32,495	9,682	24.4	27.0	1.3	35.5
Wisconsin	3,459	922	10.4	24.9	1.9	47.3
Wyoming[1]	(2)					

[1] Species reported as occurring, but no further information available.
[2] Reported.
[3] Although they are not reported in the census, there are bearing trees with salable product in Utah.
[4] Not reported.

According to these figures there is a great difference in the yields of walnut trees in different parts of the country. In the Prairie States the yield is notably low, ranging from 3.3 pounds to the tree in Kansas to 12 pounds in Illinois. Through the Lake States, the Ohio Valley States, and the Eastern States the yield runs from 25 to 40 pounds, and in the Gulf States and the Carolinas it is reported to be 50 to 90 pounds. These differences may not be due so much to climatic causes as would at first appear. The lowest yields are from regions in which the most trees are reported and in which walnut flourishes naturally. It is probable that in this region many of the trees are of natural growth, in mixture with other hardwood species that would tend to reduce the production. In the Gulf States, in which the maximum yields are reported, the trees are practically all planted. Furthermore, the reports are in all probability mostly from single trees planted in the open; and this would account, in some measure at least, for the high yields. The prices are much more uniform than the yield, indicating that they are dependent not so much upon demand as upon the minimum cost of production and marketing. This cost ranges from 1 cent a pound in Missouri to 2½ cents in New York. In the New England States, where walnut is not native, but is planted to a limited extent, the prices are still somewhat higher than in New York. The maximum income per tree, naturally therefore, comes from the region of greatest yield of nuts per tree. The income and yield are both highest in the South and lowest in the Prairie States.

Of all the nut trees that may be planted, black walnut is probably the best in all the region from Tennessee and western North Carolina northward and eastward to the limits of the natural growth. Even here, however, the nut-growing business is so unorganized that it is difficult to say what value it has to the farmer. Certainly this crop is not able to compete with general agricultural crops on the high-class soils demanded for the growth of walnut at the present time, in spite of the fact that the costs of labor in growing and handling the crop are lower than the costs for handling agricultural crops.

The culture of black walnut is similar to that of pecan and English walnut, which it resembles in soil and light requirements. Seedling walnuts usually begin to bear at about 20 years of age and continue in full vigor for a long period. Grafted trees usually begin to bear much earlier, but it takes 10 or 12 years for the development of sufficient crown to allow a heavy production of nuts. At present there are several horticultural varieties in the market budded from trees that have exceptionally good nuts for cracking, but there are few bearing trees from such stock and it is difficult to forecast their yields and value.

Trees planted to the north of the natural range of black walnut bear small numbers of nuts, and the size is below normal, although the quality is reported to be as good as farther south. It has been the experience in England that this kind of nuts give rise to weak seedlings and should not be used for propagation purposes.

ESTABLISHING WALNUT PLANTATIONS.

METHODS OF PLANTING.

Walnut may be grown successfully either directly from the nuts sown where the plantation is to be made or from young nursery stock. Growing walnut directly from nuts is naturally much the cheaper method. The nuts may usually be gathered at simply the cost of the labor. They could be bought, even on the retail market in 1918, for 7 cents a pound, or approximately $2.50 for 1,000 nuts. One-year-old seedlings from a nursery would, on the other hand, cost $15 to $20 a thousand. The proportion of nuts failing to germinate would usually be about equal to the first year's loss with nursery stock. On this score there is, therefore, no advantage in the more expensive stock. In starting the stand from nuts the chief danger has been that, as planting is usually done in the fall, the nuts would be destroyed by rodents during the winter. If squirrels and mice are not plentiful, however, this is the cheapest and simplest method.

The nuts are gathered in the fall after they have dropped naturally from the trees, and may be planted immediately, before the ground freezes, without being shucked. They should be placed in shallow holes made with a mattock, so that they will lie about an inch and a half deep. When, as will often be the case, the planting is in sod, it may be facilitated by first plowing furrows, in which the nuts may be planted at regular intervals. This also permits a better early development of the seedling by freeing it from competition with weeds and grass. If plowing is not practicable, the sod should be removed with a spade or mattock for a foot about the spot where the nut is planted. To insure a full stand of seedlings from the beginning, it is best to plant two nuts in each hole, for some of the nuts planted will not germinate at all and some not until the second year. If the nuts are of usual quality, however, 80 per cent will germinate within two years, and a great number of spots will have two trees in them. By the third or fourth year, when the seedlings are well established, even if both appear vigorous and of equal development, they must without fail be reduced to one tree to the spot, or the thrift of the trees will soon suffer.

If there is danger from rodents, or if it is desired to allow hogs to run on the planting site during the fall and winter, the nuts may be planted successfully in the spring. Spring planting requires more

FIG. 1.—BLACK-WALNUT REPRODUCTION ALONG A FENCE ROW IN INDIANA.

FIG. 2.—TO A CONSIDERABLE EXTENT HOGS PREVENT THE REPRODUCTION OF BLACK WALNUT.

FIG. 1.—SPROUT REPRODUCTION FROM ROOT COLLAR.

FIG. 2.—SPROUT REPRODUCTION THAT HAS BEEN FOLLOWED BY BUTT ROT.

care and is more bothersome, but it avoids the rodent problem without making necessary the purchase of expensive nursery stock. After the nuts are gathered in the fall they should be stored for the winter by "stratifying"; that is, they should be placed in layers separated by moist sand, either in a rodent-proof pit in the ground or in a box in a cool cellar, or some such place. Freezing once or twice is not detrimental, but repeated freezing and thawing while the nuts are in the moist sand will cause the death of the seed. The sand must be kept moist, particularly toward the spring, the time for germination to take place. The nuts must be carefully watched at this time. When they split and the radicles appear it is time to plant. The stratified nuts are dug up, and those showing growth are carefully placed in baskets for planting. Sometimes the shells are loose, and the radicles somewhat developed; considerable care is then needed in handling and planting these nuts to prevent fatal injury. A shallow hole should be dug with a mattock in either a plowed furrow or seed spot cleared of grass, and a single nut should be placed in each hole, with the radicle pointed down. The nut should be covered about 1½ inches deep, and the soil should be firmed over the top with the foot. Some of the nuts will remain in stratification, because germination either has been delayed or has entirely failed. These nuts should be put back in the sand and left for possible use the next spring, for, even with the most careful handling, there will be some unoccupied spots in any plantation. These vacancies may be filled the following spring from the supply of nuts in stratification, the sprouting of which may have been delayed until then. Because of the short time between planting and the appearance of the young trees, and because of the abundance of other natural foods in the spring, the danger from squirrels is a negligible factor, and the planting of nursery stock or home-grown trees is very rarely necessary.

Planting walnut seedlings is rarely warranted, in view of the two cheap and simple methods above described. The expense involved in planting seedlings is greater than in the case of many other tree species, because of the long taproot which even 1-year-old trees possess. If for any reason it is desirable to plant seedlings instead of nuts, it is not difficult to grow them in a nursery. Nuts may be planted in the fall in a bed prepared as for any garden crop. They should be spaced 2 or 3 inches apart in rows 6 inches apart. The seedlings should be cultivated and cared for during the first year, and should be set out the following spring in their permanent places, in large, deep, properly spaced holes. Care must be exercised in the transplanting because of the length of the young taproot. A seedling left in the nursery bed for longer than one year will develop such a

deep-feeding root system that transplanting soon becomes very expensive and is liable to result in injury to the roots and, possibly, in the subsequent death of the seedlings.

SPACING.

The spacing depends altogether upon the kind of plantation the owner intends to have. If he intends to bestow careful management upon his trees and get the best results from them, the initial spacing should be close (4 by 4 feet), and thinnings should also be made without fail when the crowns begin to interfere with one another. If, on the other hand, the owner plants the trees as a side line, to add to the appearance of his farm, protect his stock, or occupy some out-of-the-way corner, and if it is his intention to let them develop as they will, a much wider spacing is advisable—say 6 by 16 feet. If they are planted closer the trees are liable to enter into active competition before they become merchantable. If they are uncared for they will so interfere with each other that after a time none will have much value; in extreme cases, decay and death may overtake the trees before they are merchantable. If the trees are grown for the production of nuts, a spacing of 50 to 60 feet would be advisable.

Although walnut is too coarse branched and thin foliaged to make a first-class windbreak, it may sometimes be desirable to plant it in single rows for this purpose. In single rows close spacing is admissible even if it is not expected that the trees will be carefully managed, for plenty of side space will be available. A spacing of 4 to 6 feet apart in the rows is satisfactory. In pastures walnut trees may be planted singly or in groups. If the trees are planted singly, a typical low-crowned spreading tree will develop that would yield one short log. This log would not be of high value, but, nevertheless, it would be merchantable. In groups of a dozen trees or so some of the trees in the middle of the group ought to produce very good logs—not of forest-grown form, it is true, but, nevertheless, superior to single trees grown in the open. Whenever planting is done the plans should provide for the maturing at one time of 40 trees at least. It is to be borne in mind that in a close plantation 80 per cent of the trees will be cut in thinnings before maturity. If he has at least 40 trees maturing at once, the owner is assured of a market at any time and a better price, as those trees will make at least 4 thousand board feet, or one carload of logs.

PROTECTION FROM GRAZING.

General grazing is not likely to harm a well-established plantation, provided too many live stock are not permitted on the area and no part of it is made to serve as a feed lot. New plantations, how-

ever, should be protected from grazing for a period sufficiently long to allow the trees to become reasonably safe from damage. The period of protection from hogs should be about three years; from cattle and horses, not less than 10 years. The farmer should, however, be cautious; and, if grazing that has been started in a plantation at the end of the tentative period of protection appears to be damaging the trees, the stock should be removed for a year or two longer. Damage from grazing results more from breakage of the trees and from trampling and compacting of the soil than from actual browsing. In one plantation in Indiana, for example, there is a large opening which resulted from the feeding of corn to hogs, a procedure that was continued through many years. The excessive trampling and compacting of the soil, together with the unusually large accumulations of manure at one place, killed out the trees. By wallowing in the depressions about the trees and laying bare the roots, hogs occasionally damage trees planted in low, moist parts of pastures. For this reason trees planted singly in pastures should be set on the slight rises or slopes rather than in the hollows. On account of the better drainage these sites dry off quickly after rains, instead of holding pools of water or mud about the roots of the trees, and consequently they provide better shade places for cattle.

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